

(12) **United States Patent**
Gettings et al.

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(54) **ROBOTIC SYSTEM AND METHODS OF USE**

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(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**

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B60K 11/06 (2006.01)
B25J 5/00 (2006.01)
B25J 19/00 (2006.01)
B62D 65/02 (2006.01)
B62D 55/075 (2006.01)

(52) **U.S. Cl.**

CPC **B60K 11/06** (2013.01); **B25J 5/005** (2013.01); **B25J 19/0054** (2013.01); **B62D**

55/065 (2013.01); **B62D 65/02** (2013.01); **Y10T 29/49826** (2015.01); **B62D 55/075** (2013.01)

(58) **Field of Classification Search**

CPC **B62D 55/075**
USPC **180/9.1, 9.32, 9.62, 9.3, 9.46, 9.28**
See application file for complete search history.

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Primary Examiner — Anne Marie Boehler

Assistant Examiner — Marlon Arce

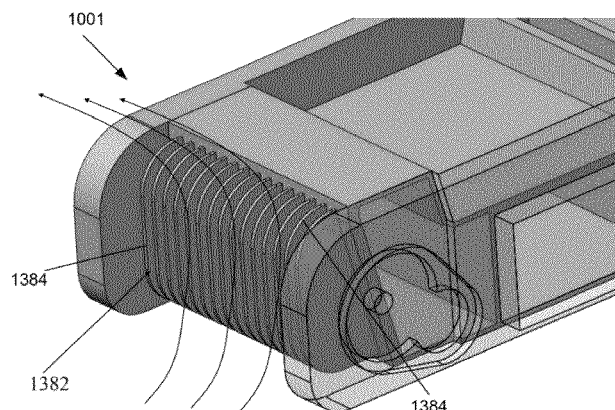
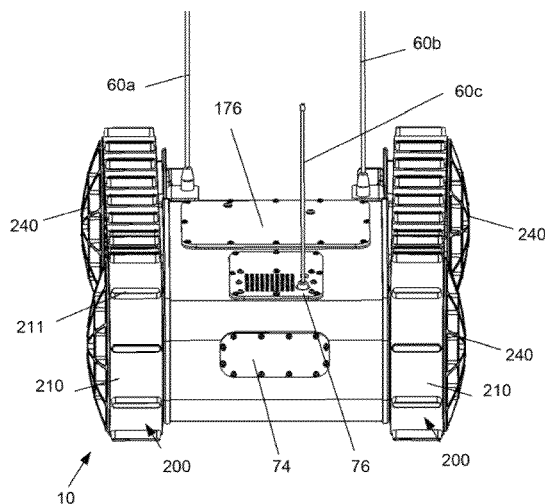
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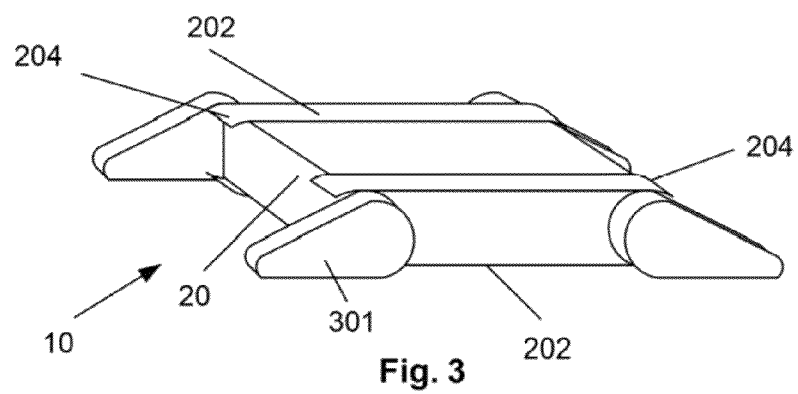
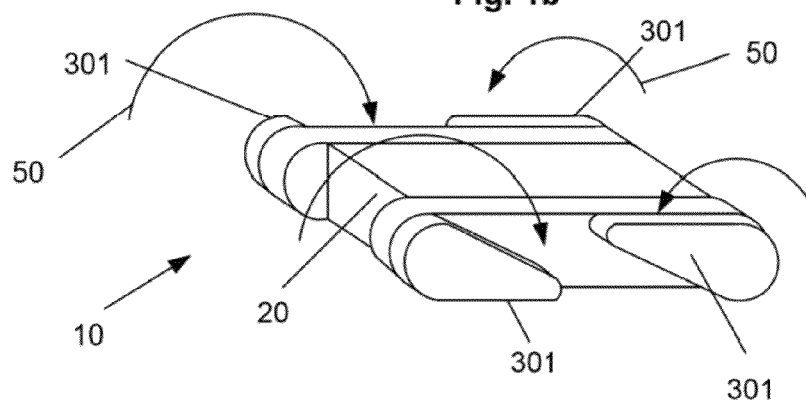
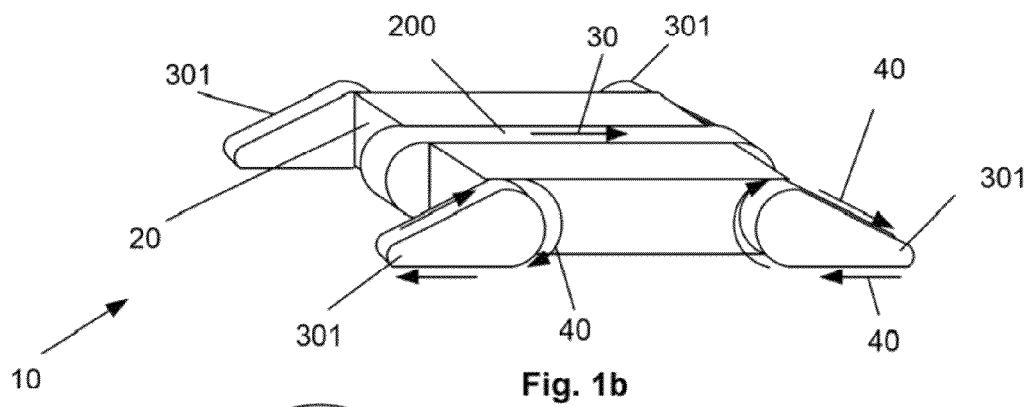
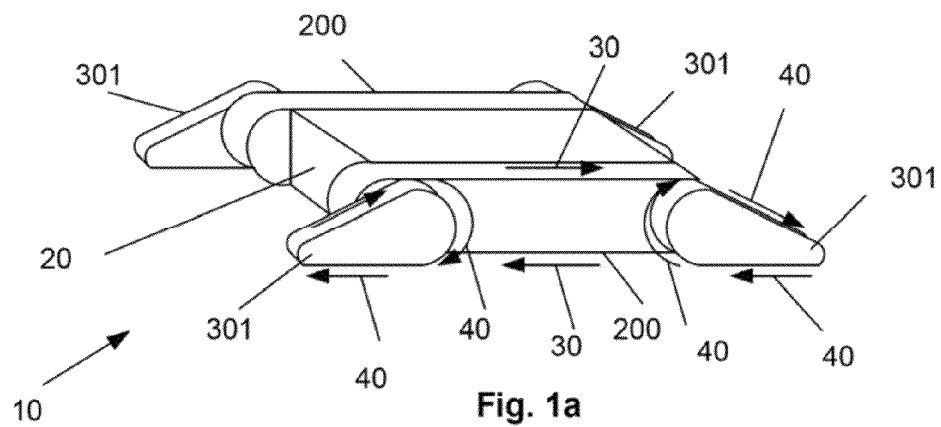
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ABSTRACT

A robotic system that can have a body and four flippers is described. Any or all of the flippers can be rotated. The flippers can have self-cleaning tracks. The tracks can be driven or passive. The robotic system can be controlled by, and send audio and/or video to and/or from, a remote operator control module. The methods of using and making the robotic system are also described.

20 Claims, 51 Drawing Sheets





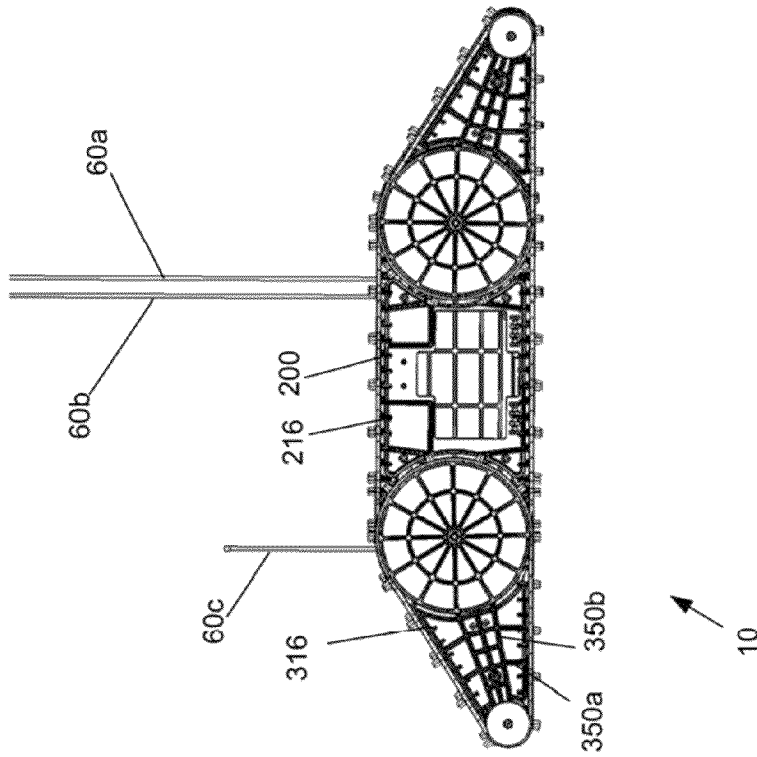


Fig. 4b

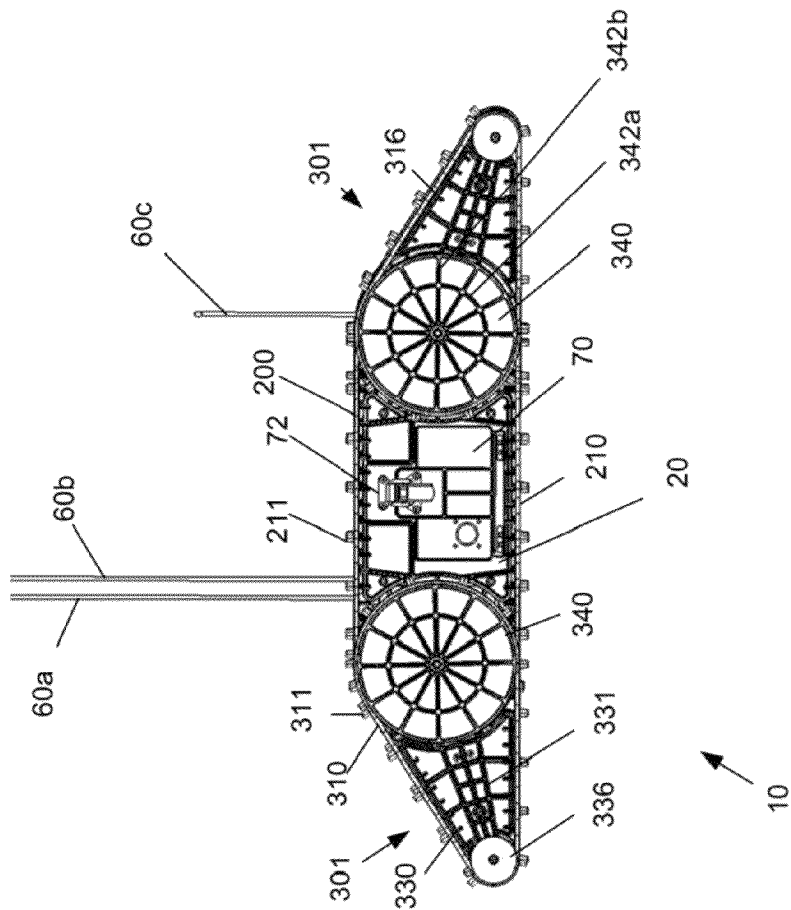


Fig. 4a

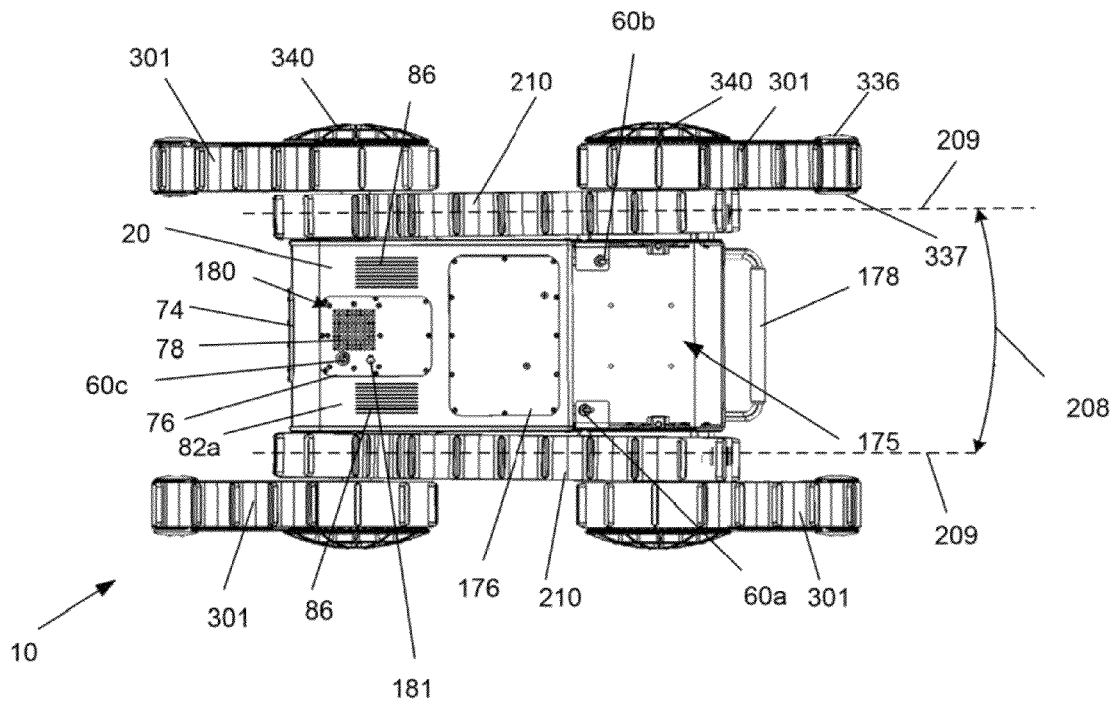


Fig. 5a

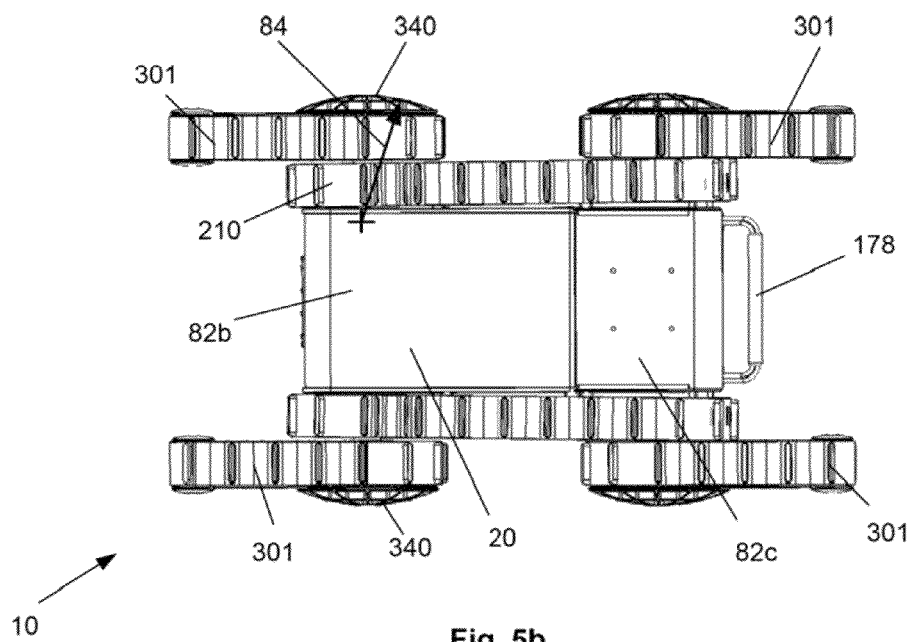


Fig. 5b

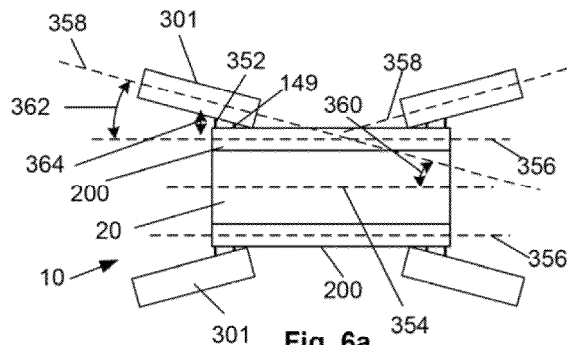


Fig. 6a

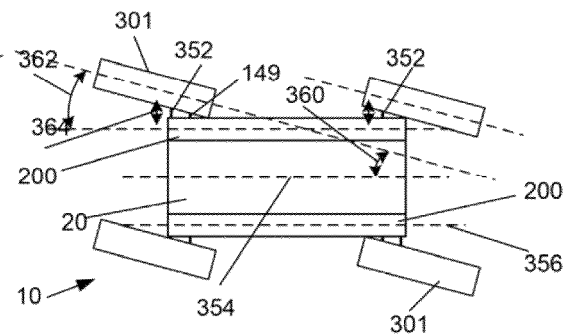


Fig. 6b

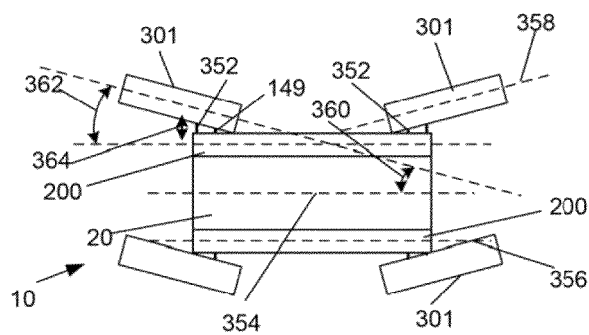


Fig. 6c

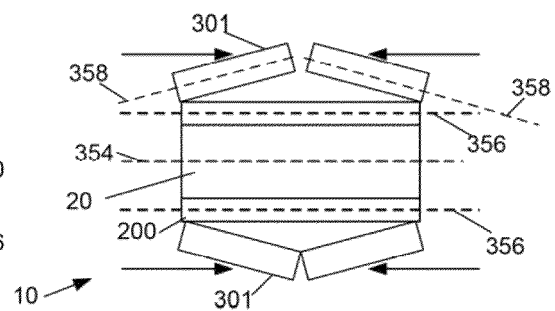


Fig. 6d

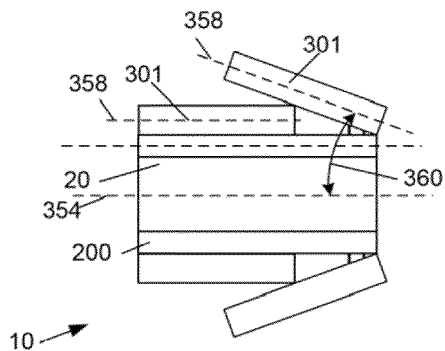


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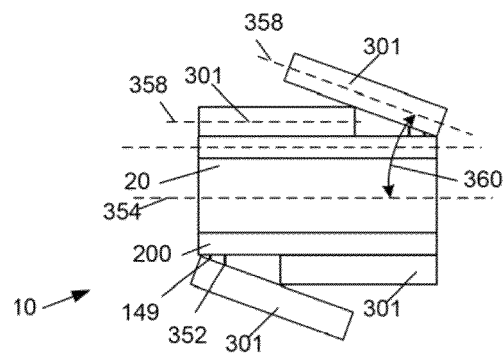
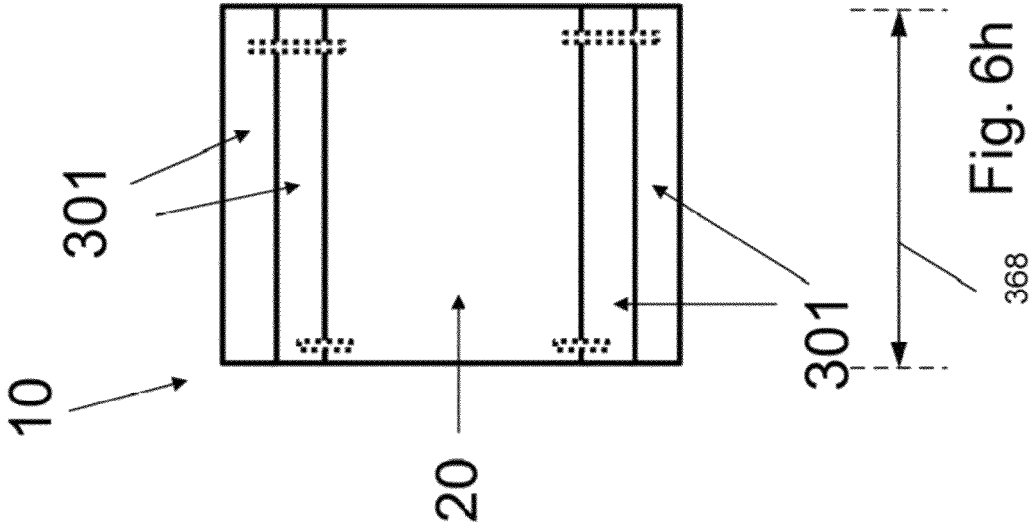
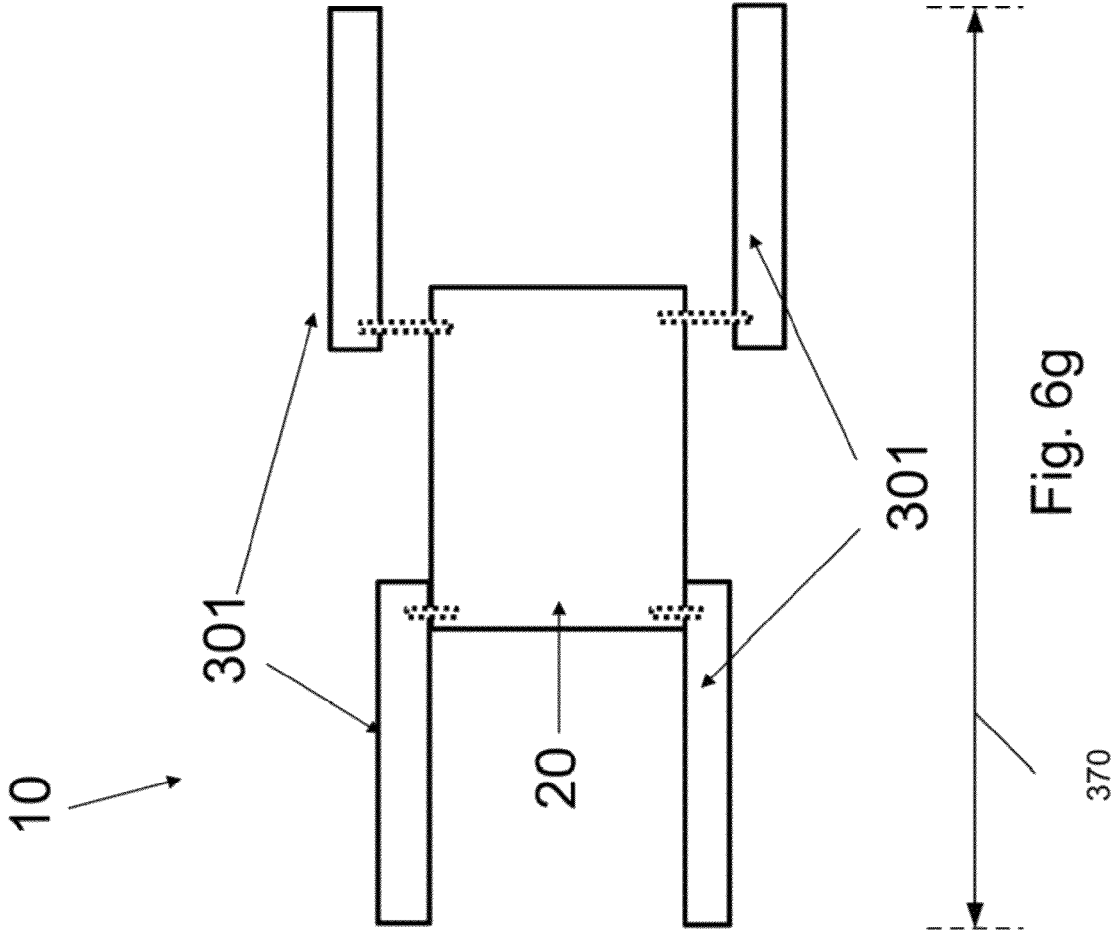


Fig. 6f



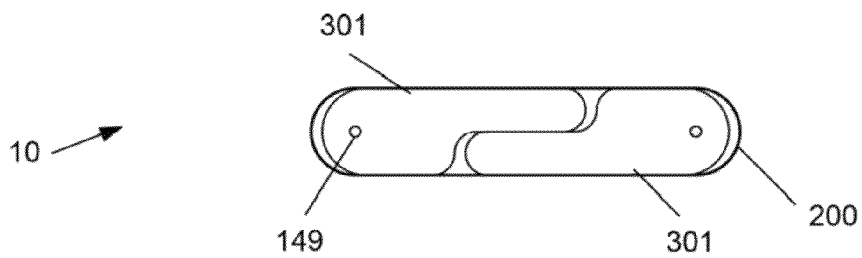


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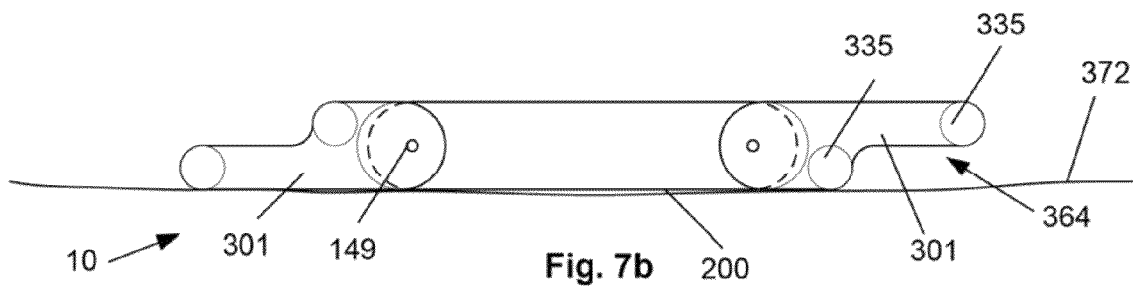


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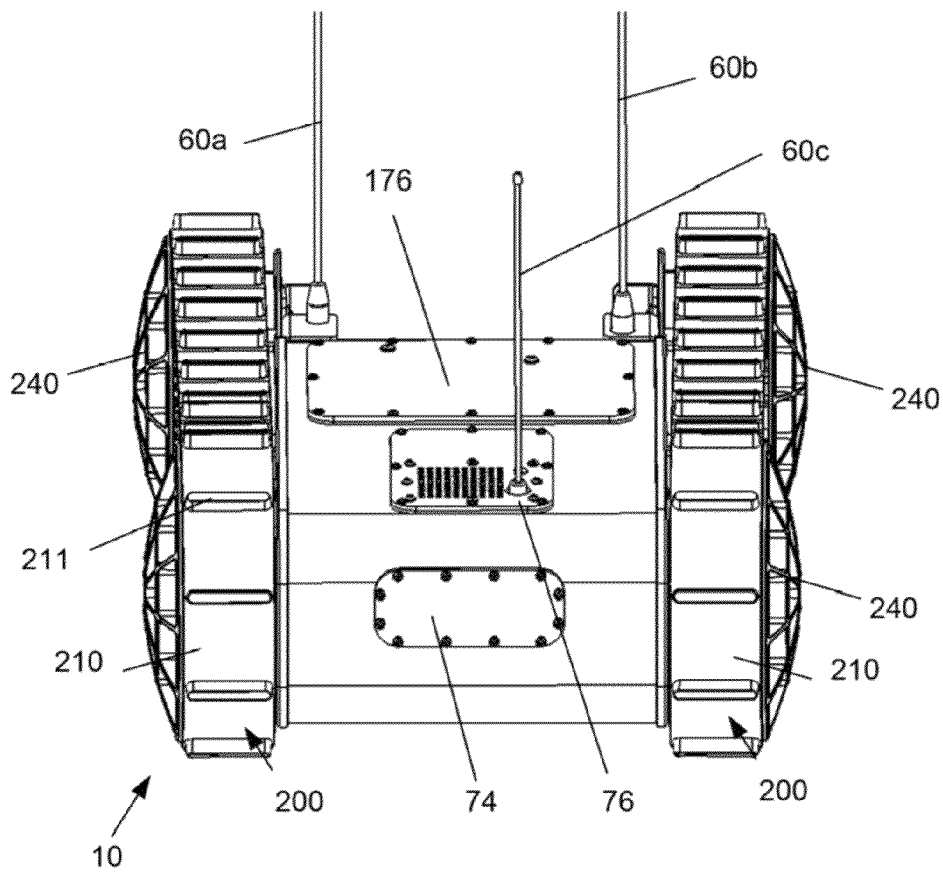
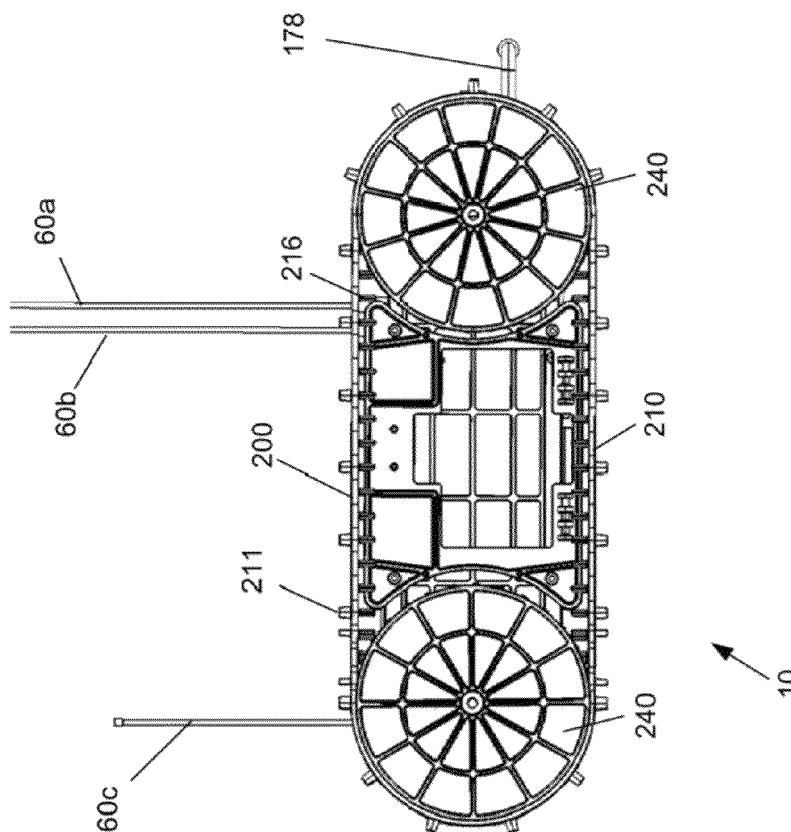
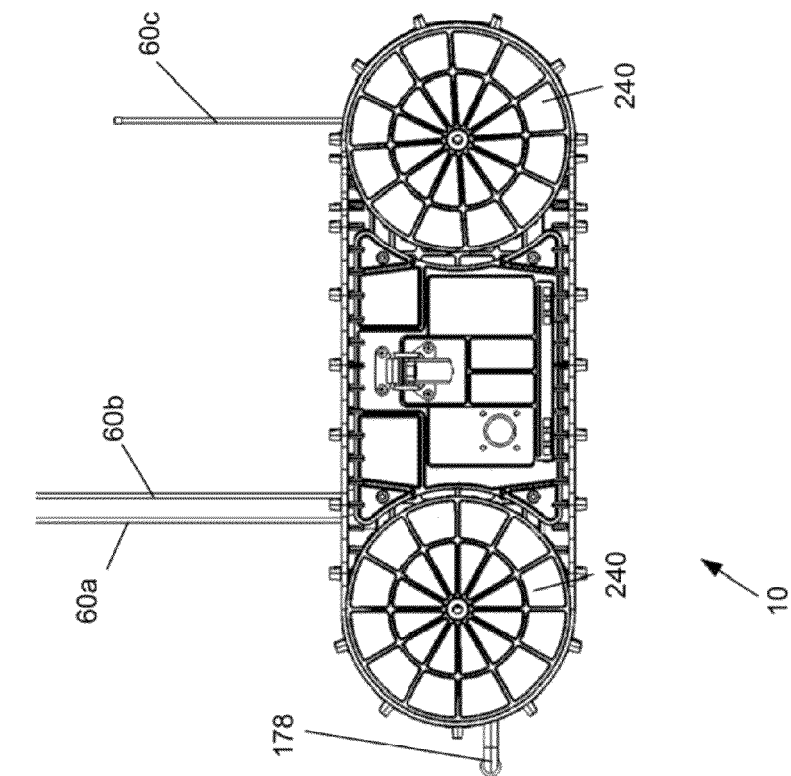
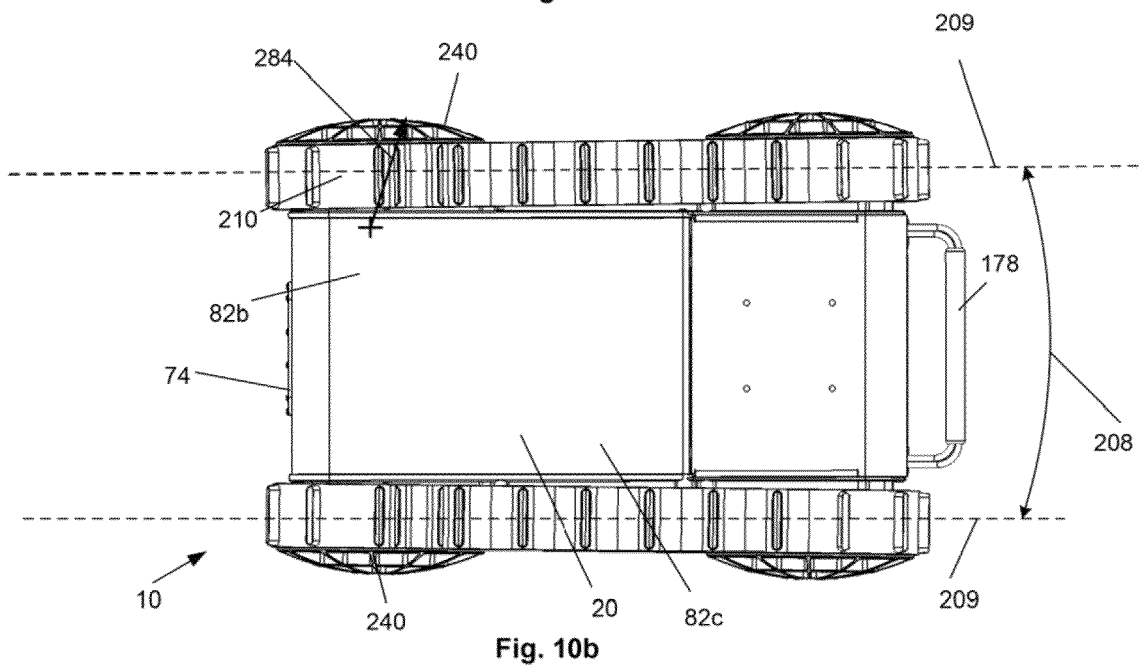
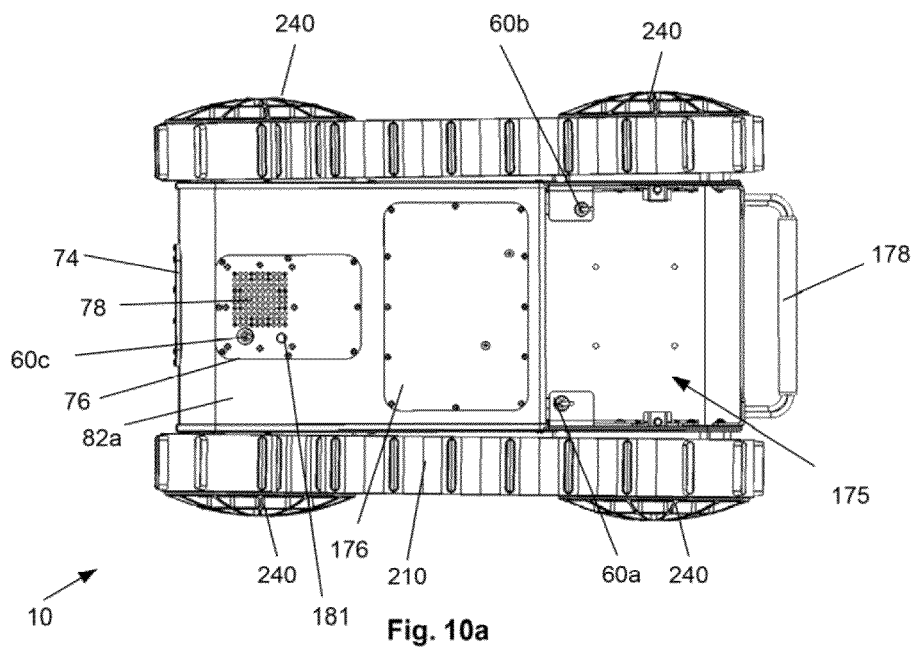


Fig. 8





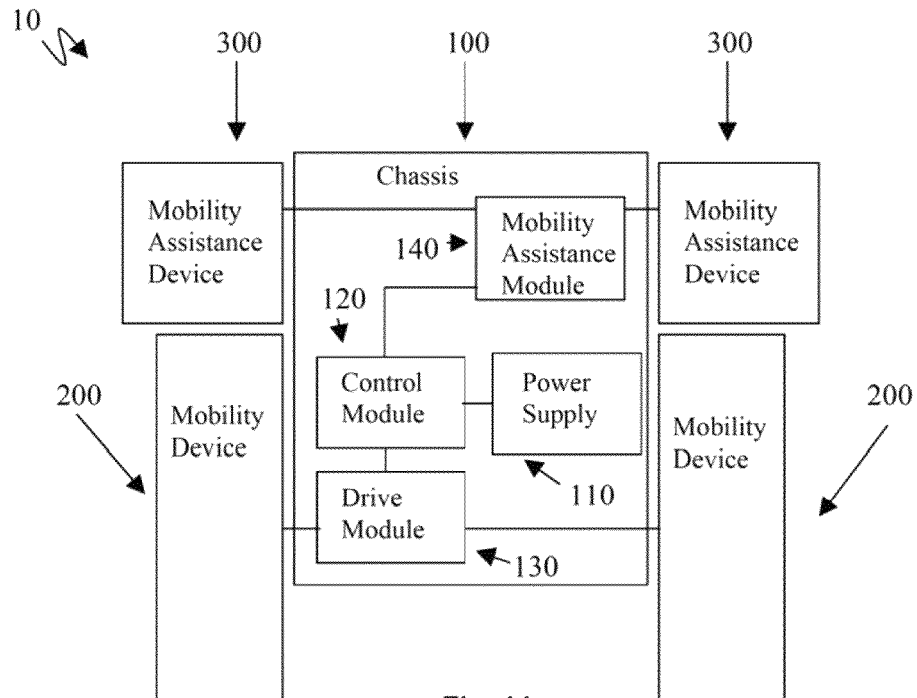


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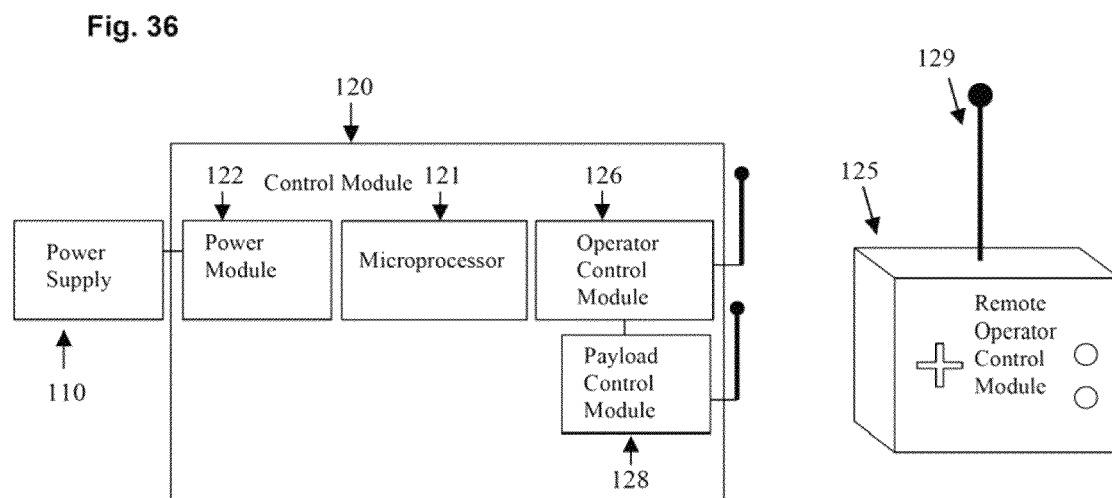


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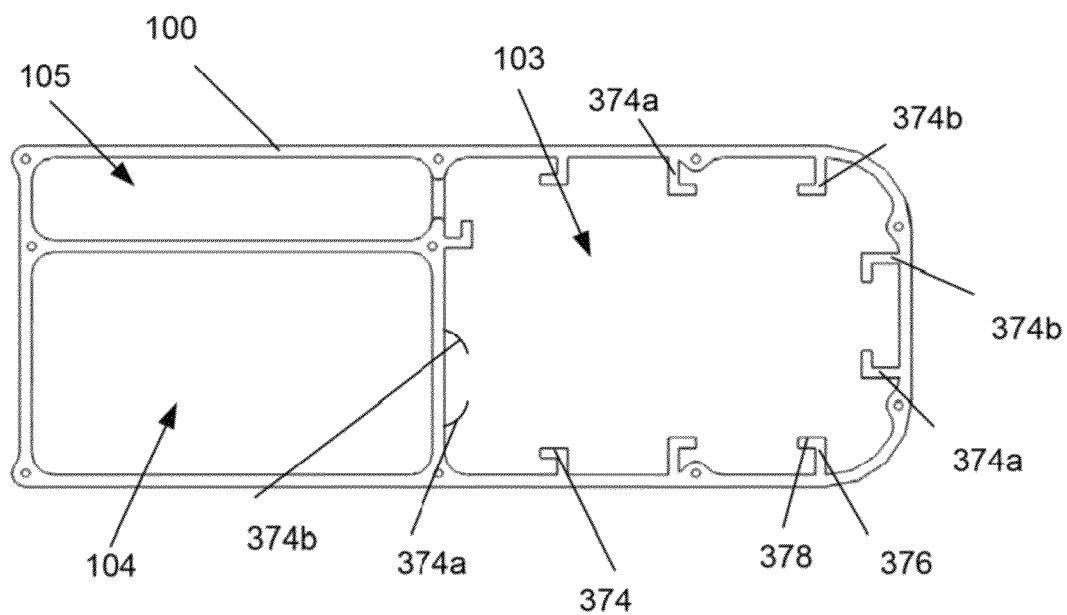


Fig. 12a

Fig. 12b

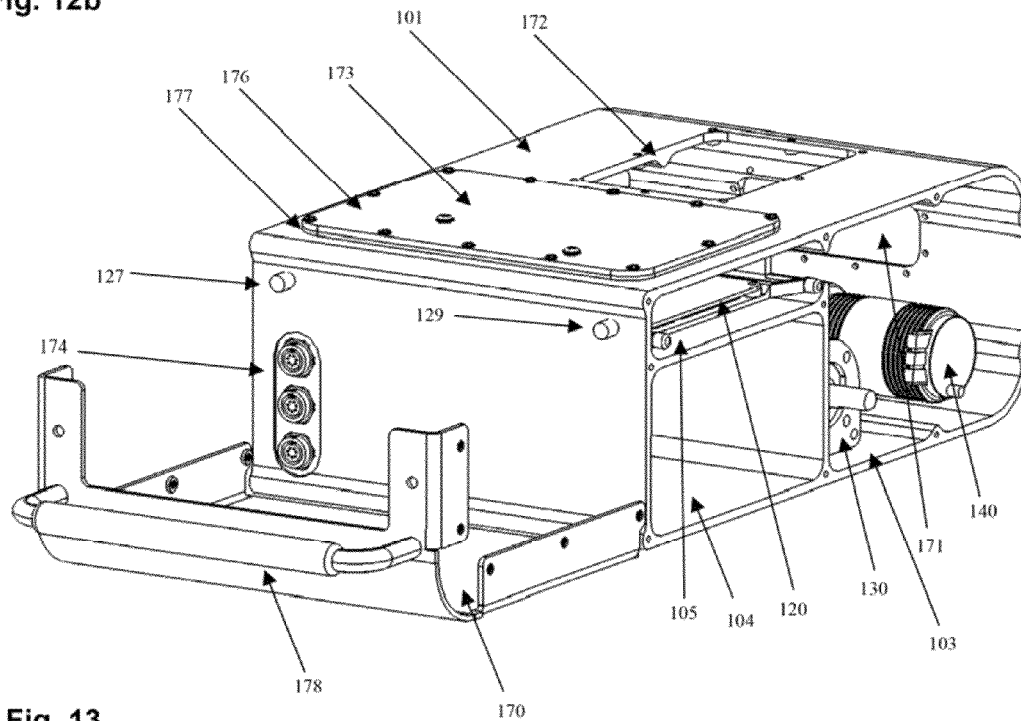
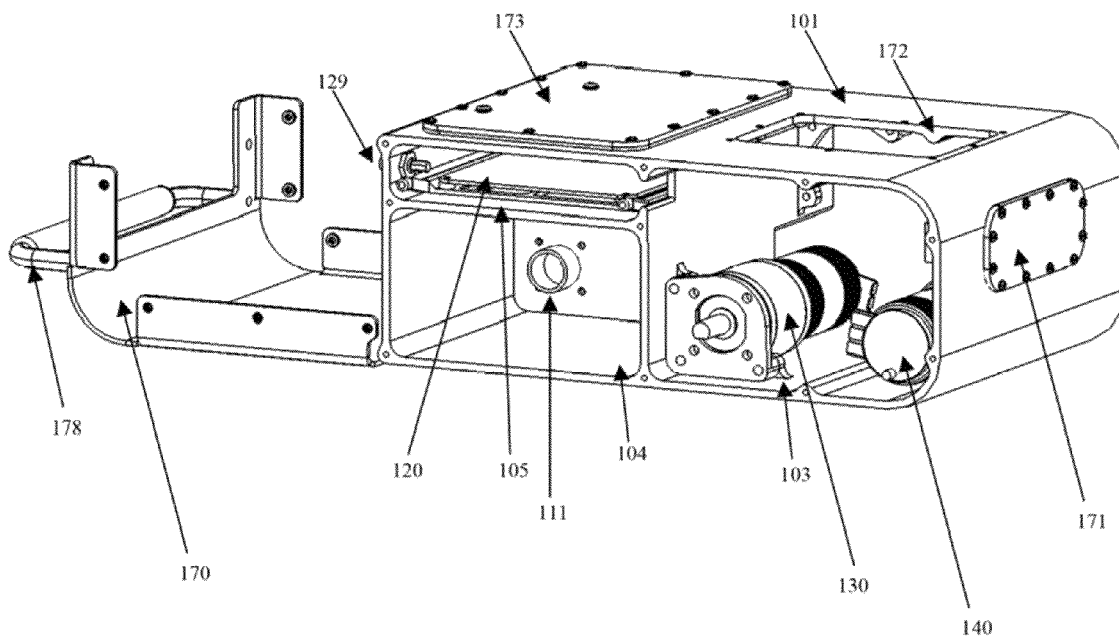


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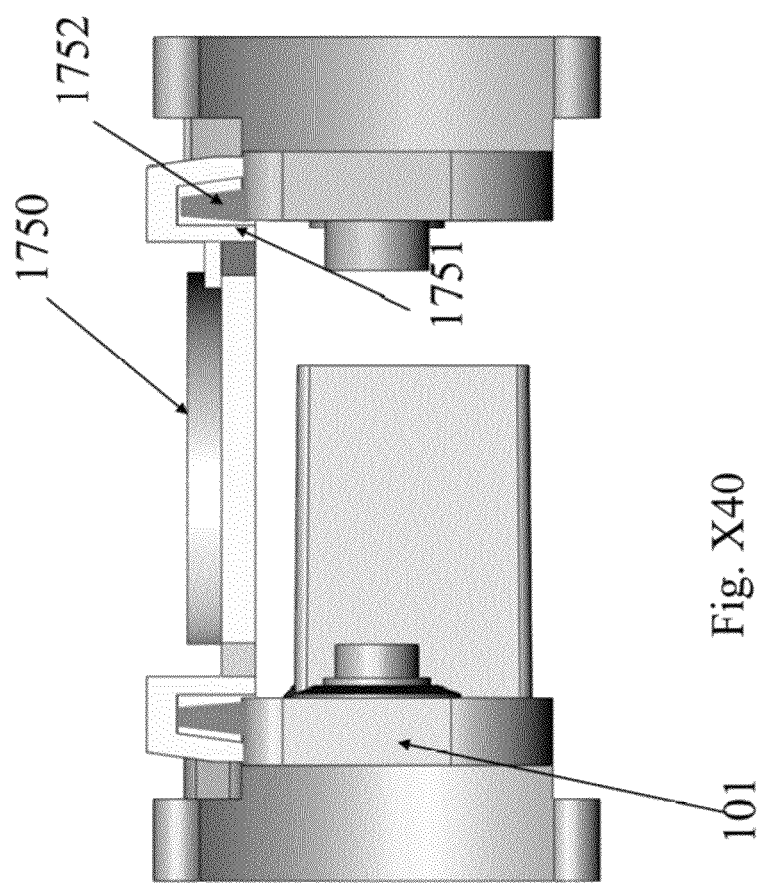


Fig. X40

Fig. 14

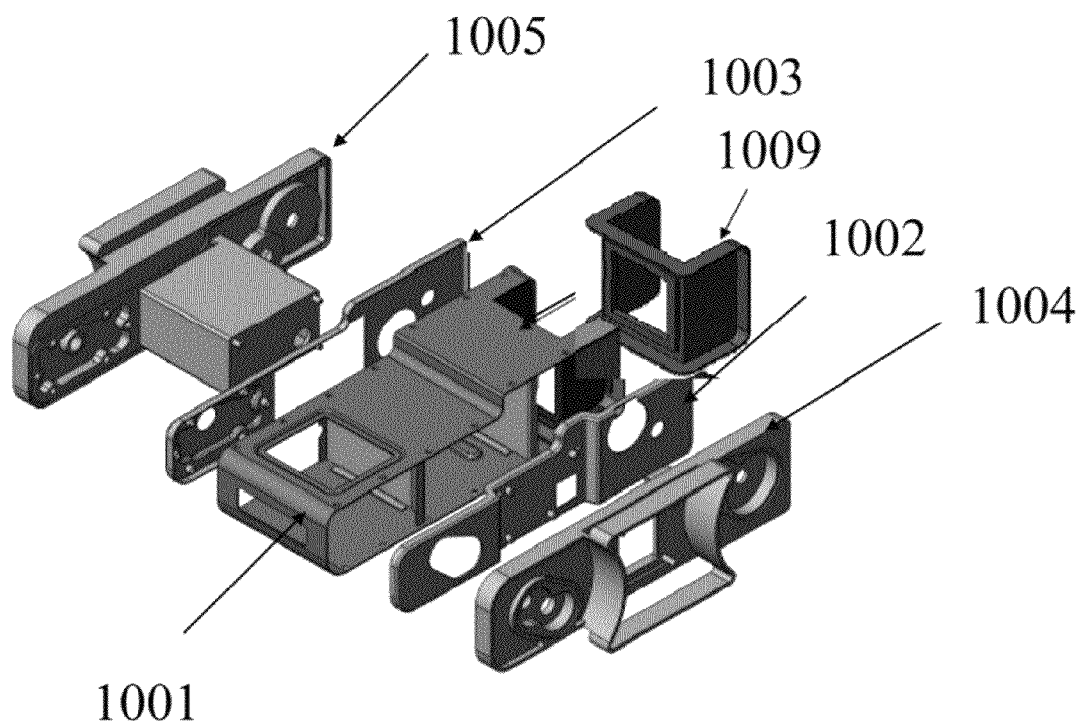


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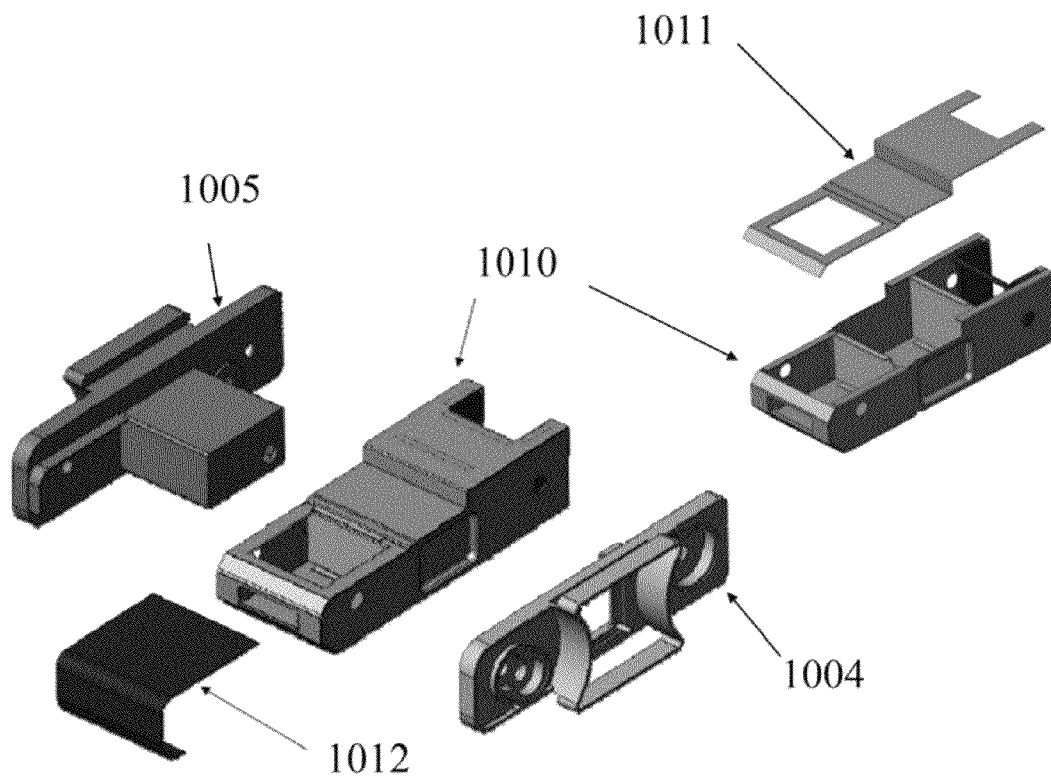


Fig. X10

Fig. 16

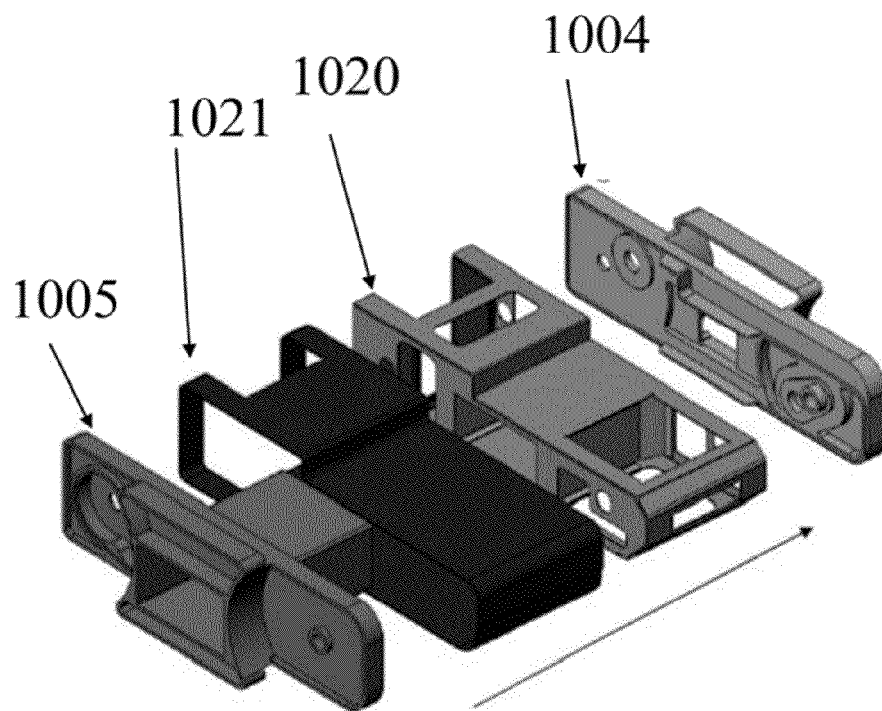


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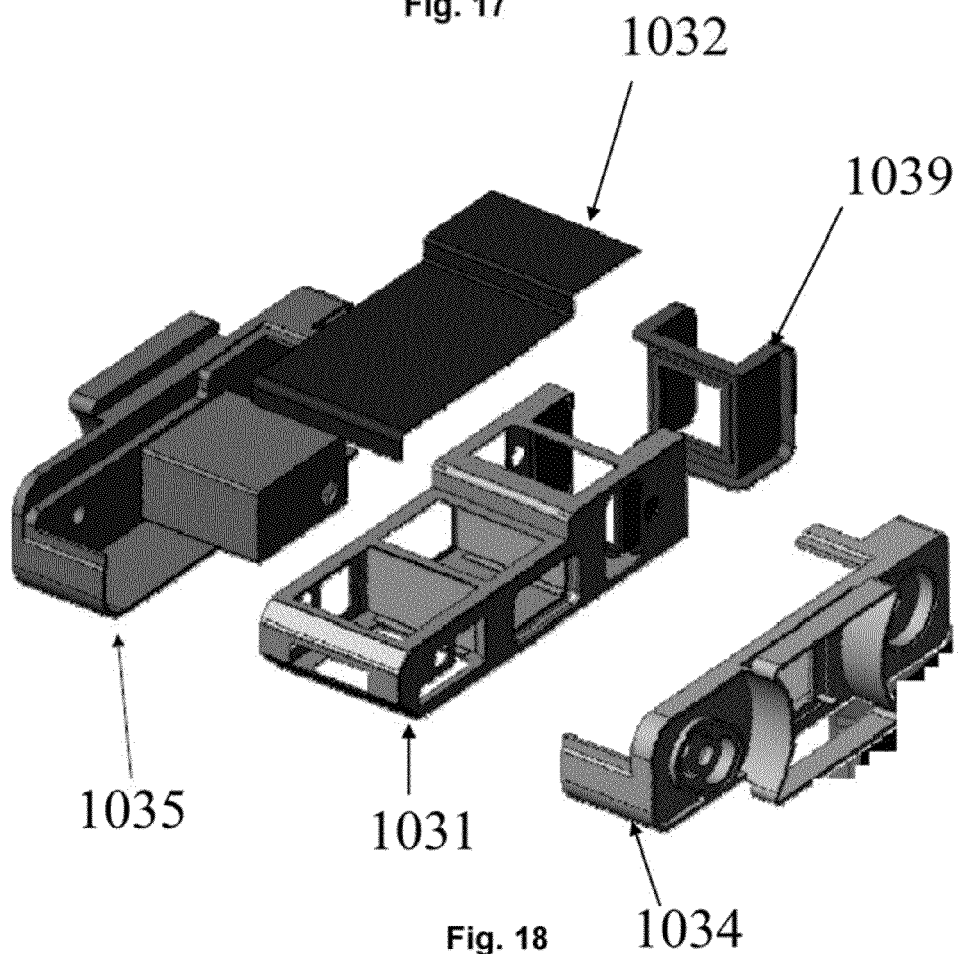
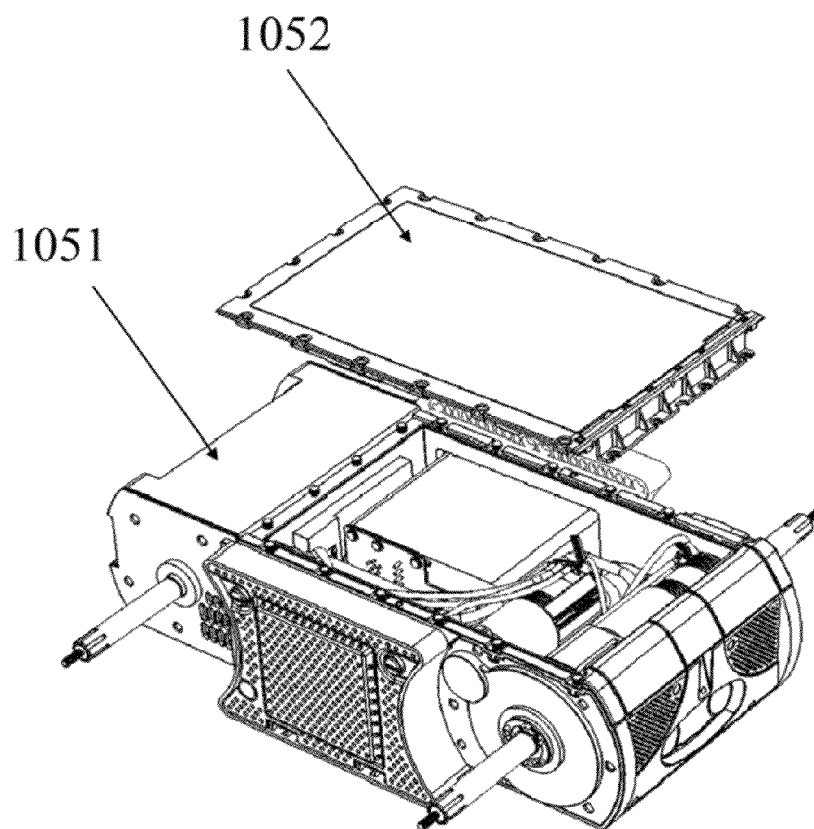
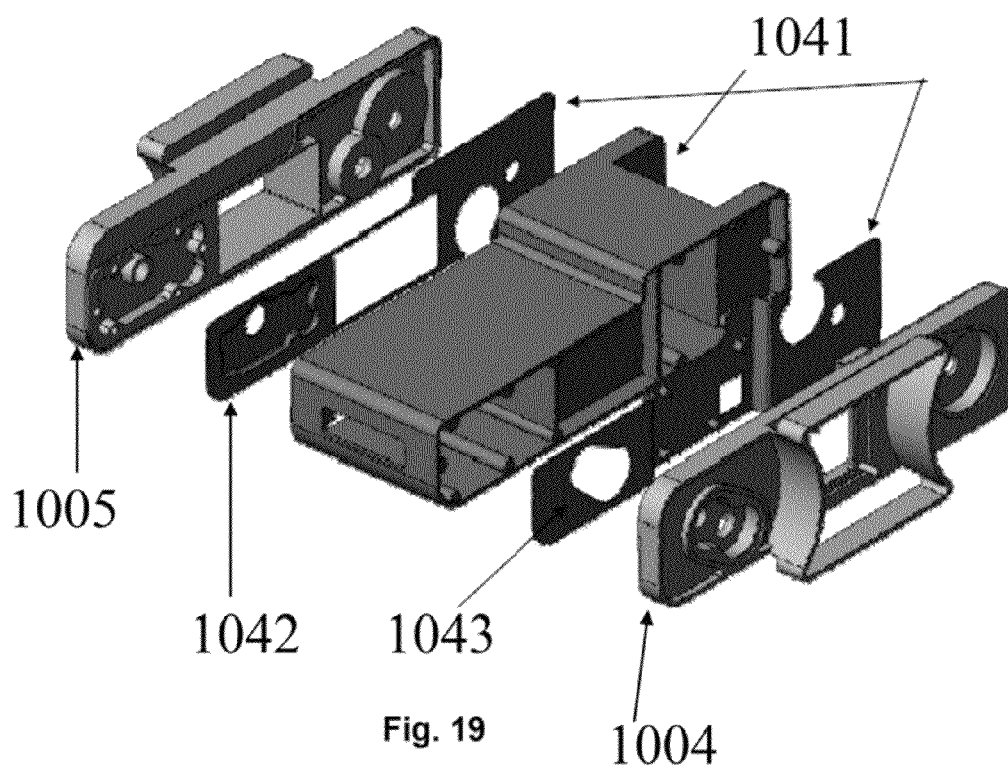


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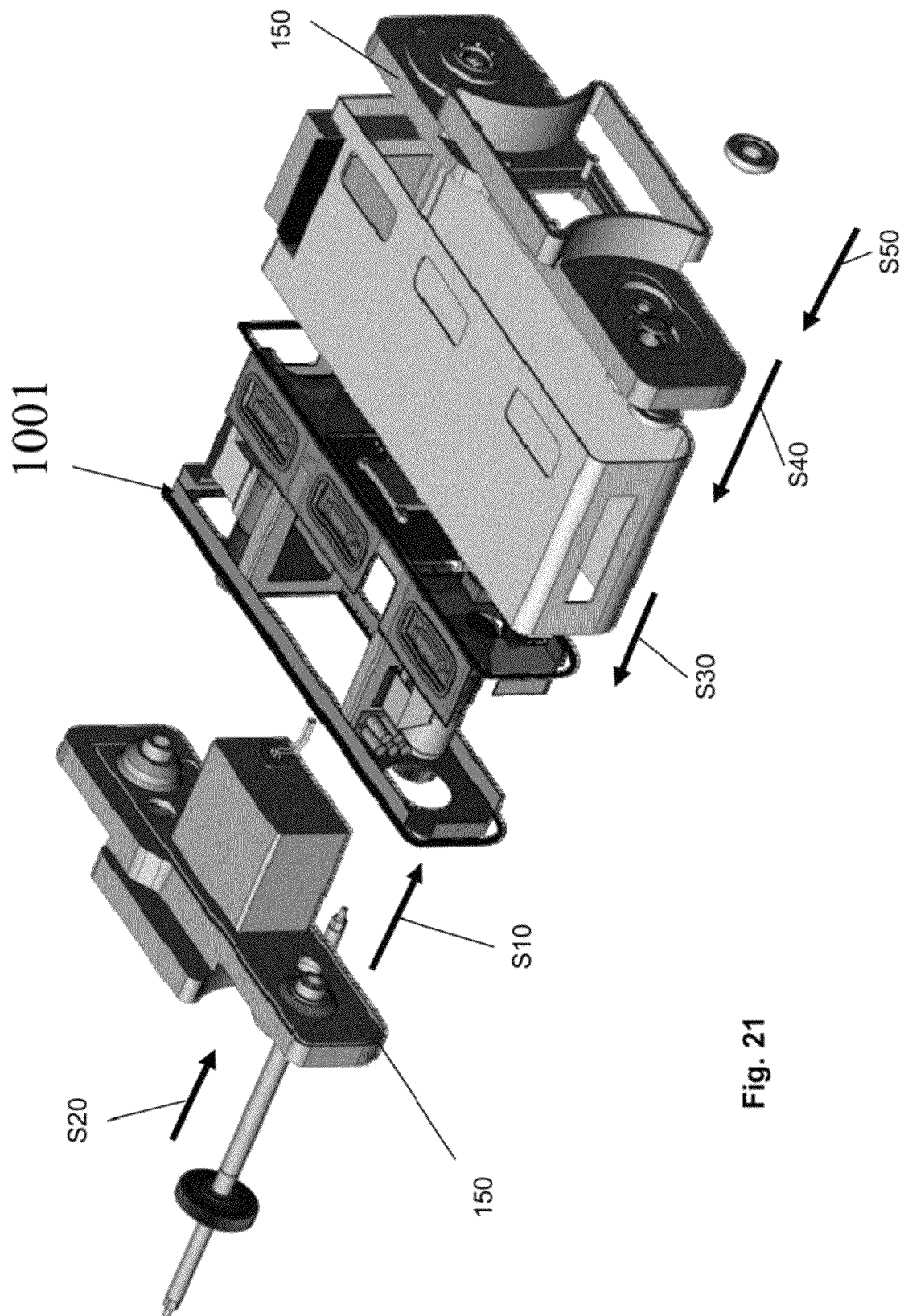


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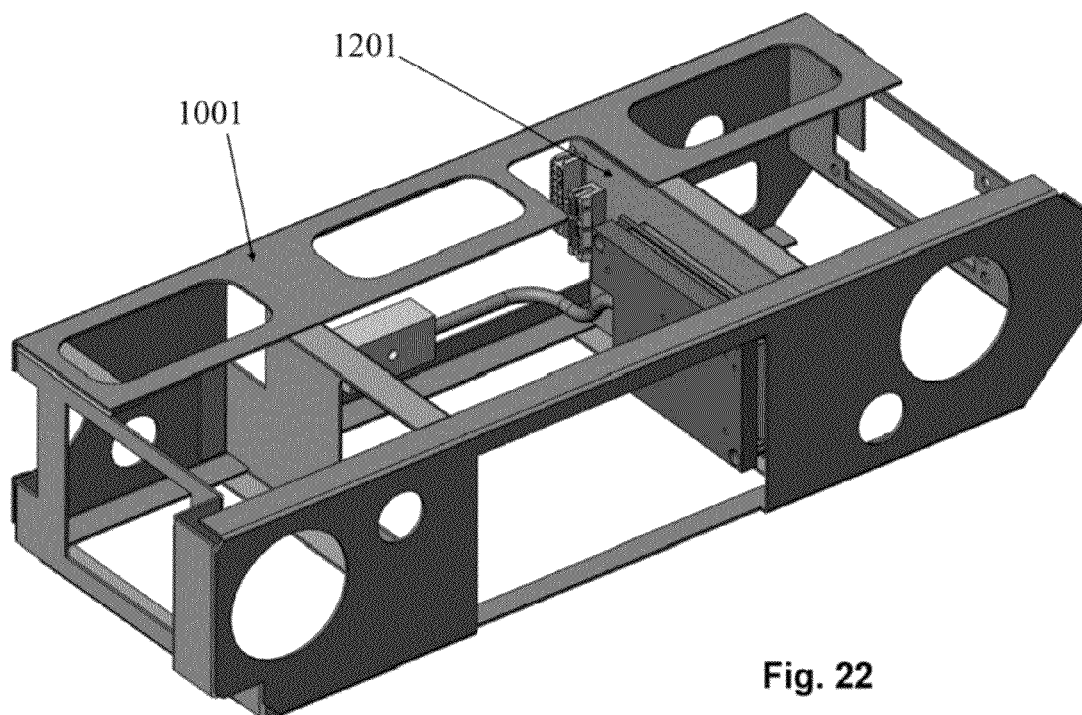


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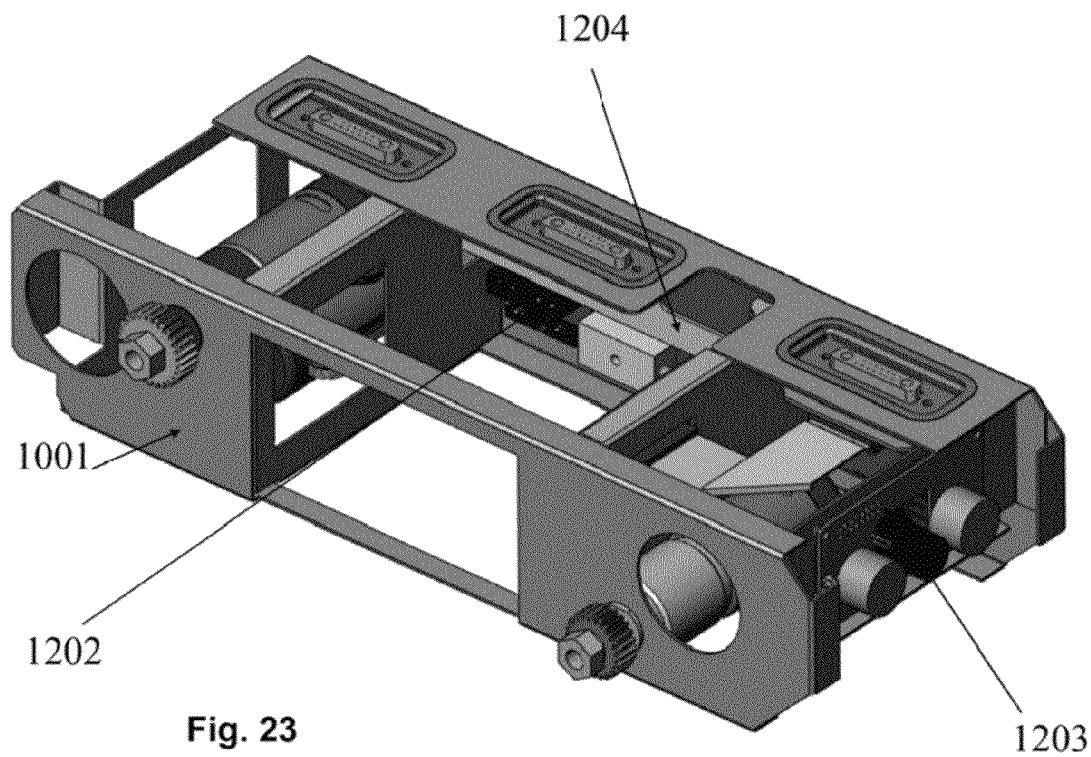


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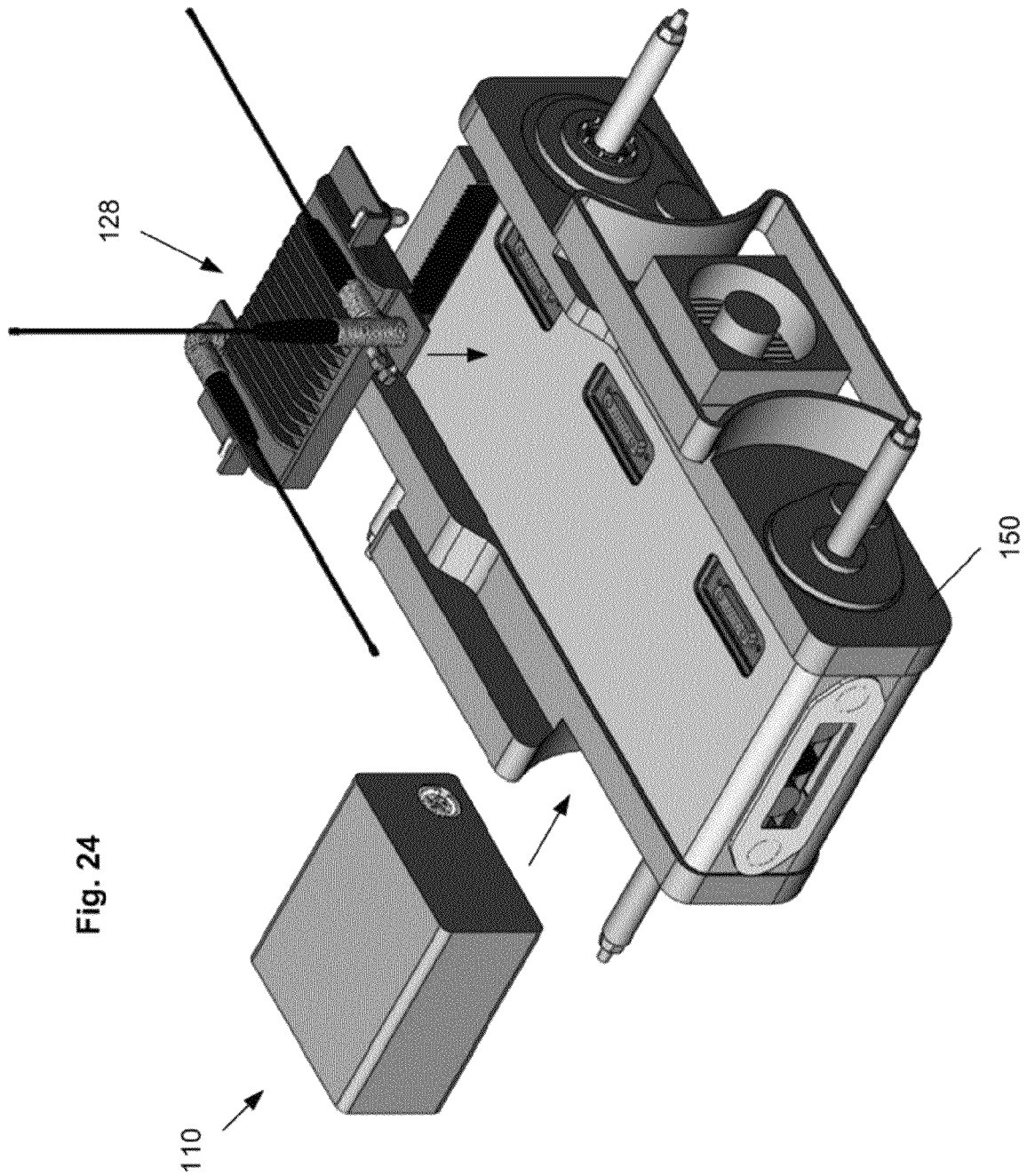


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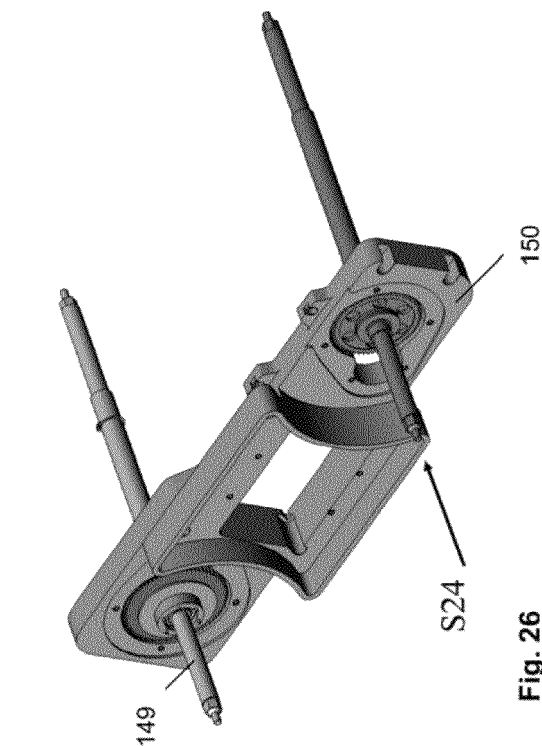


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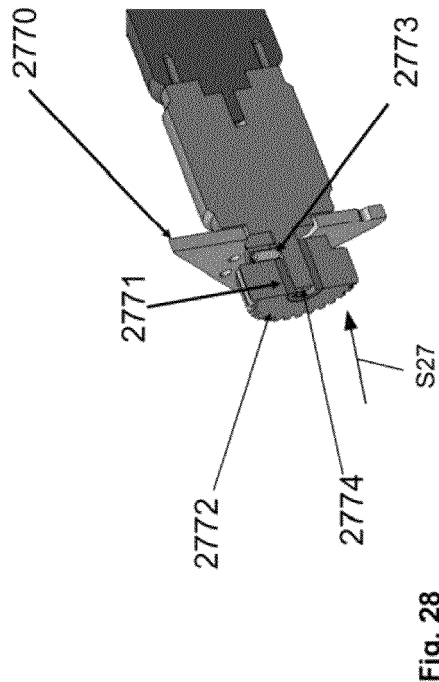


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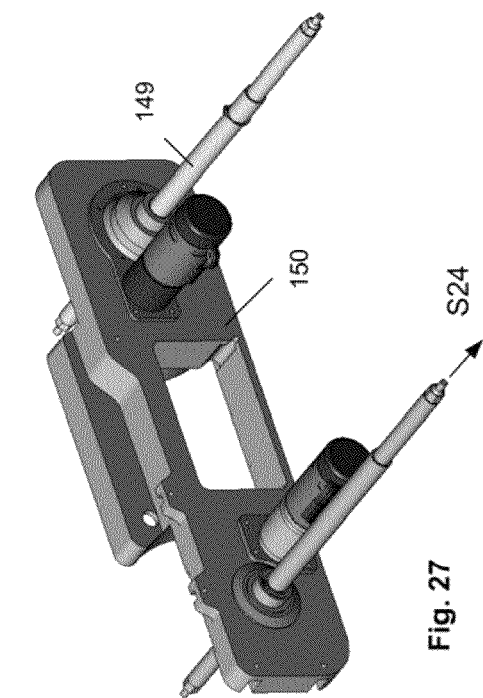


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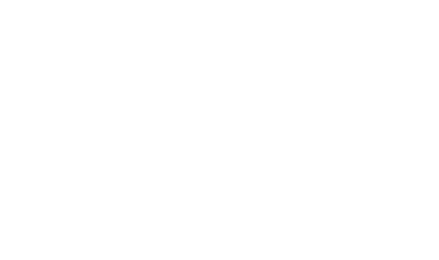


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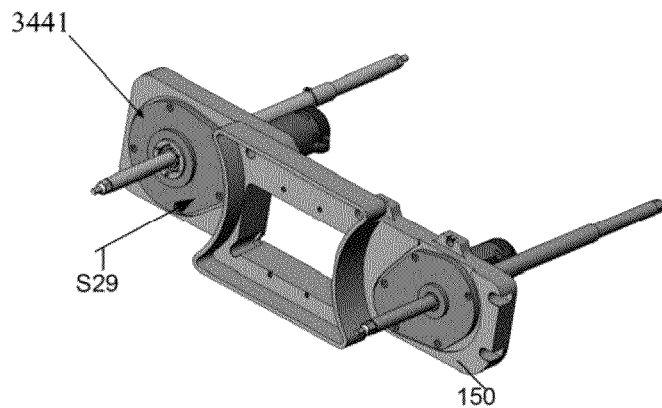
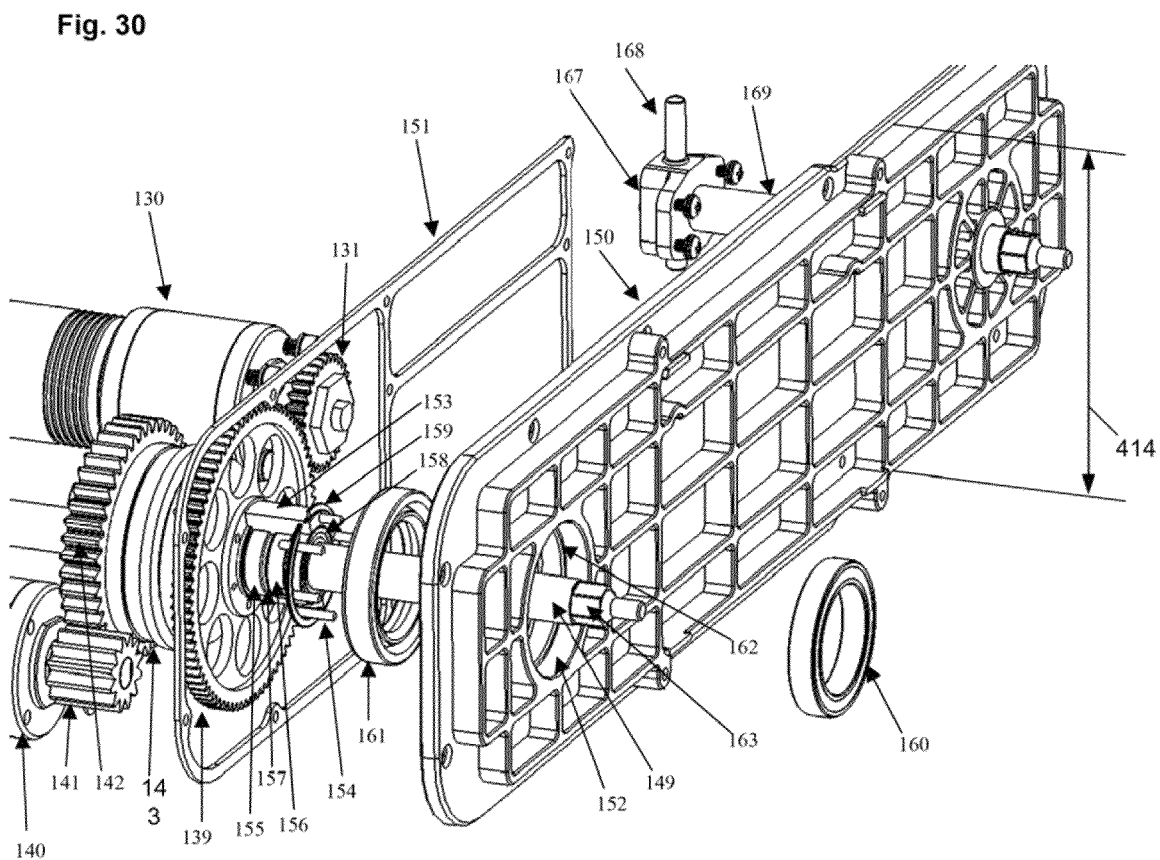


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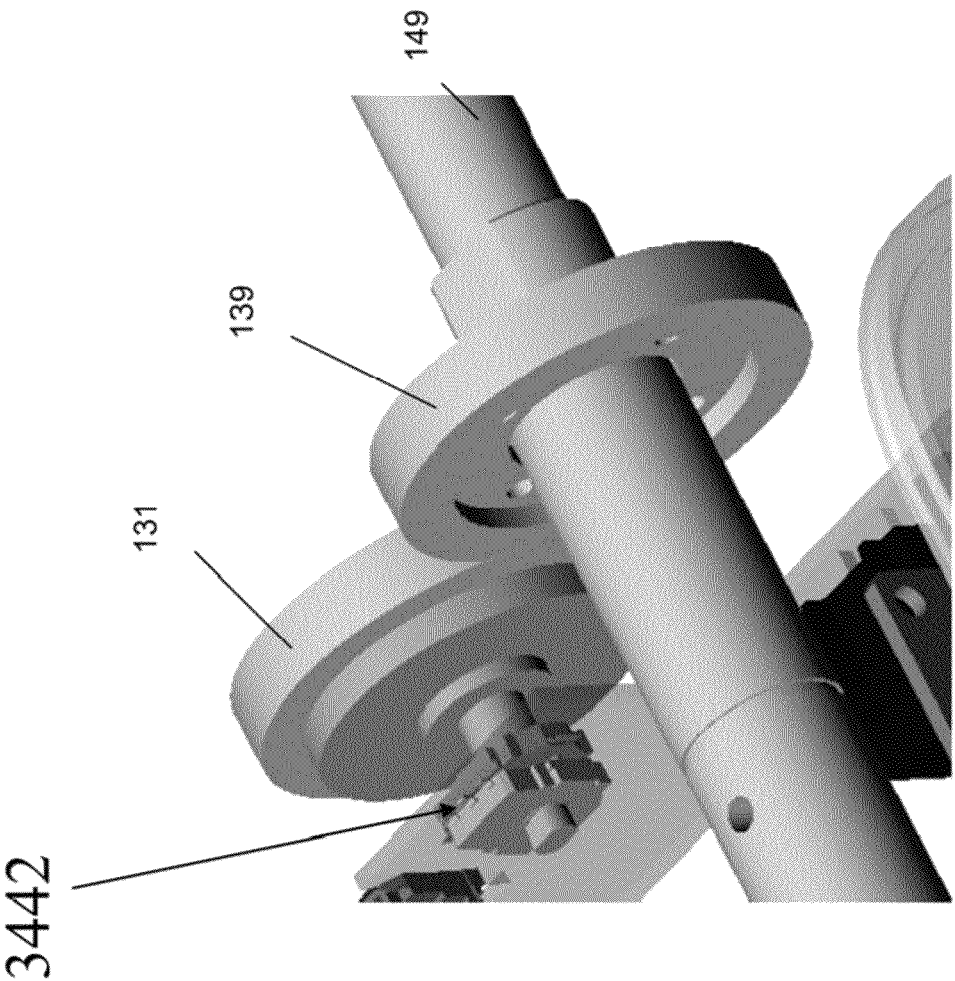


Fig. 31

Fig. 32

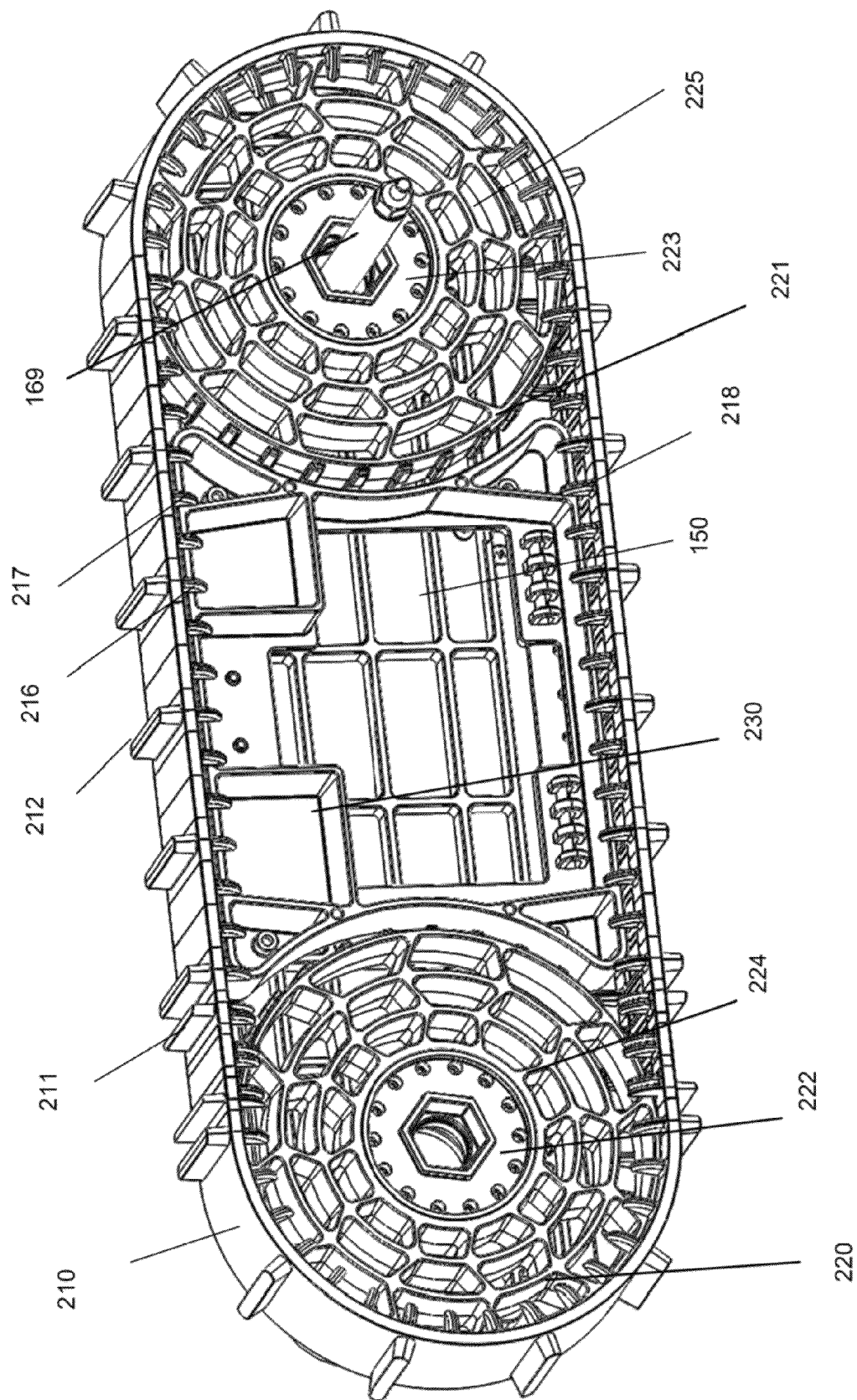
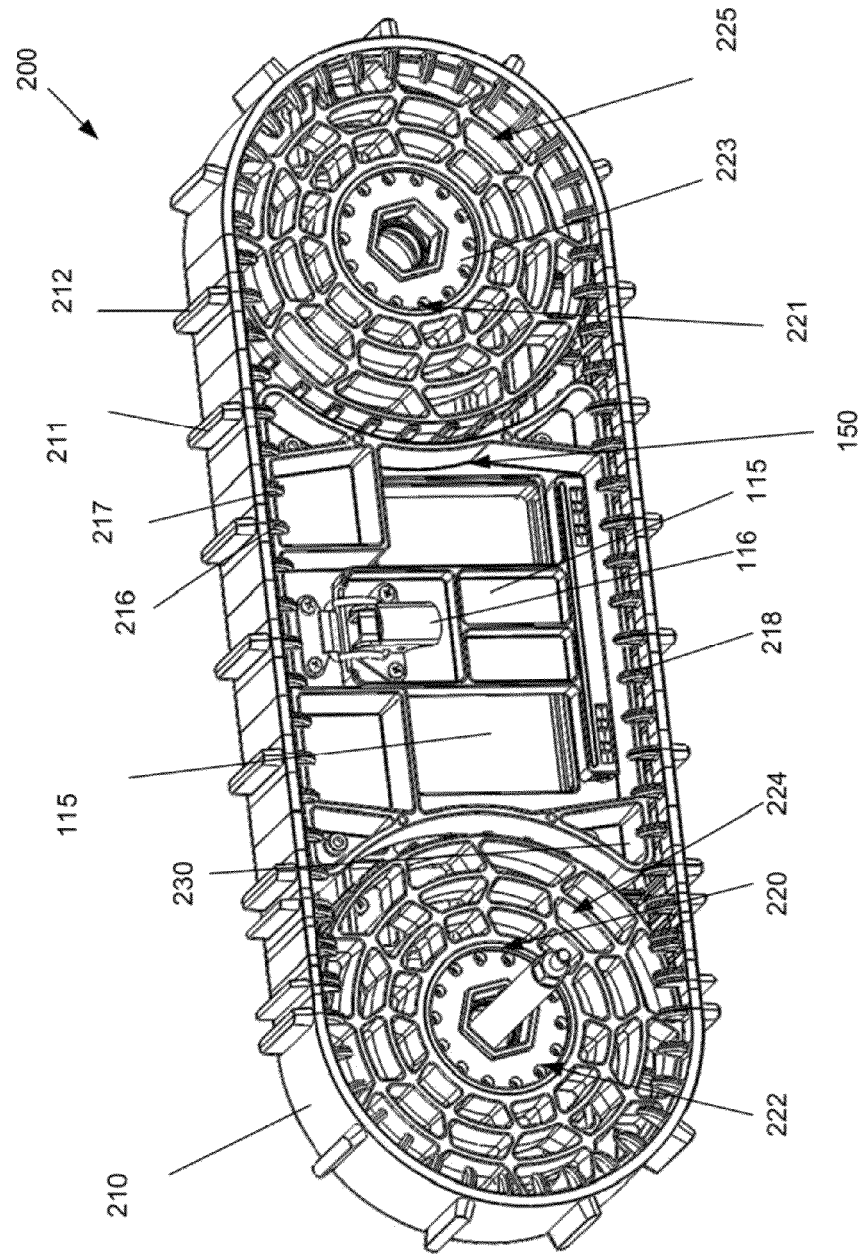
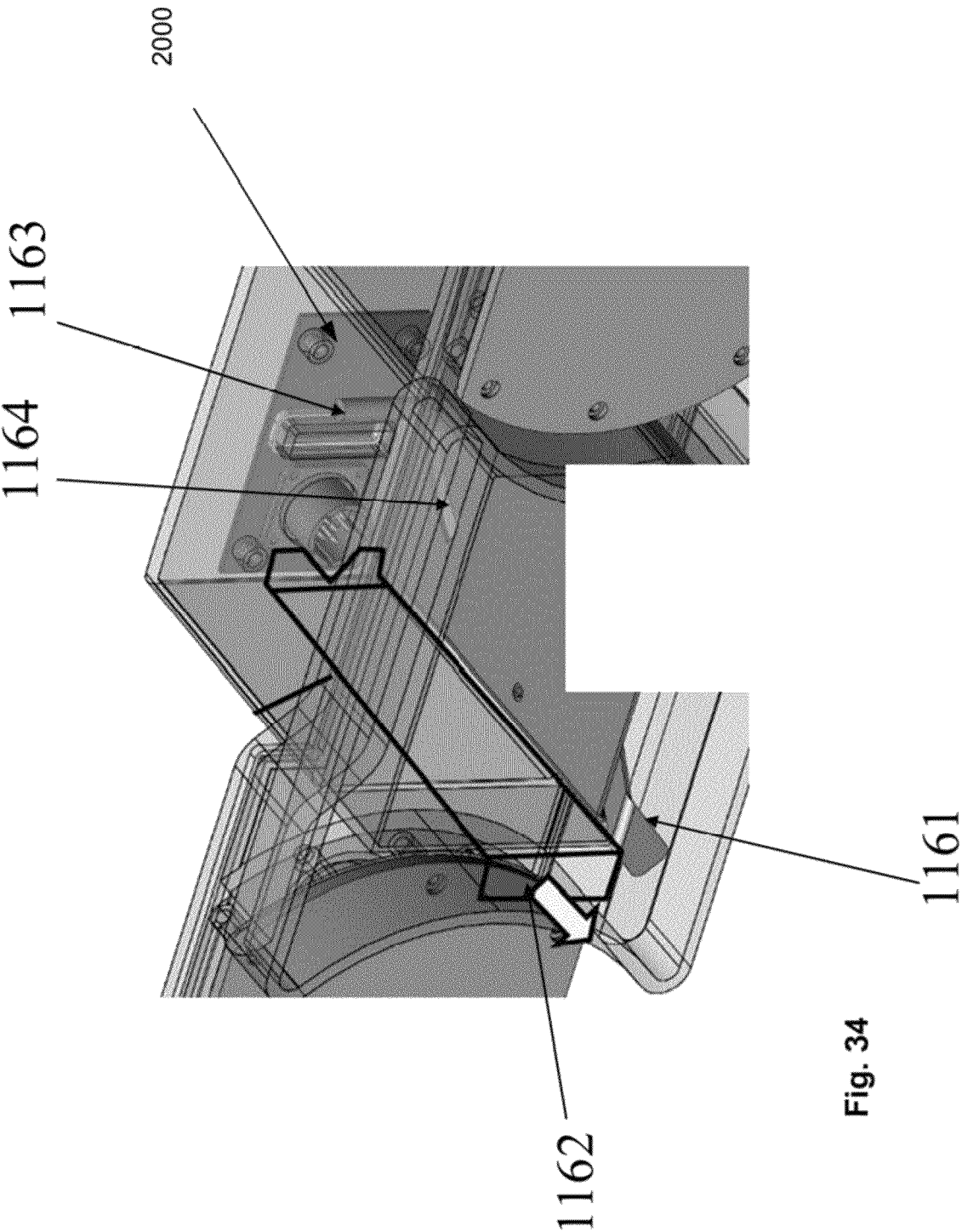


Fig. 33





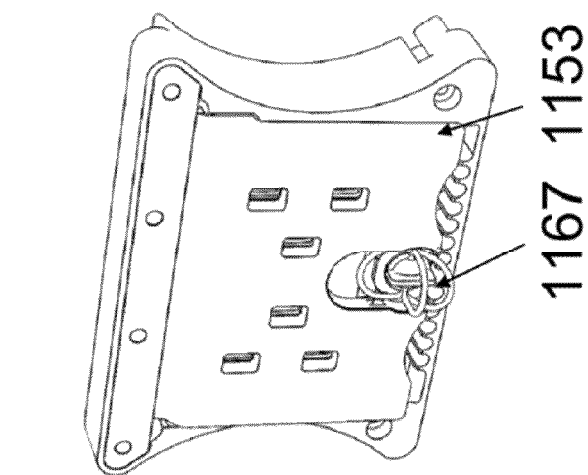


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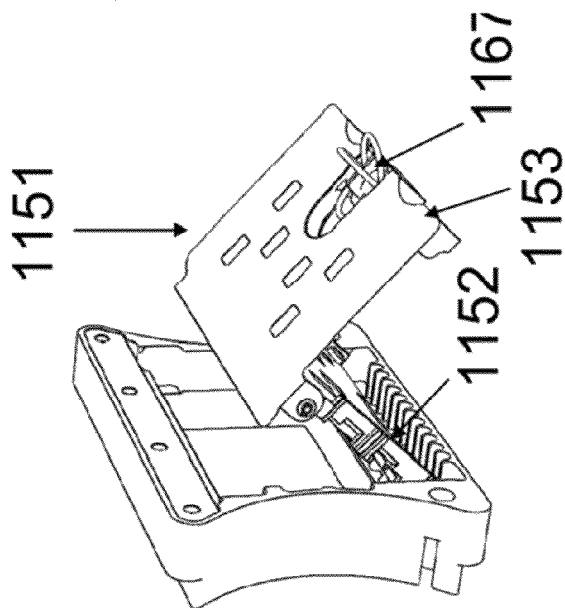


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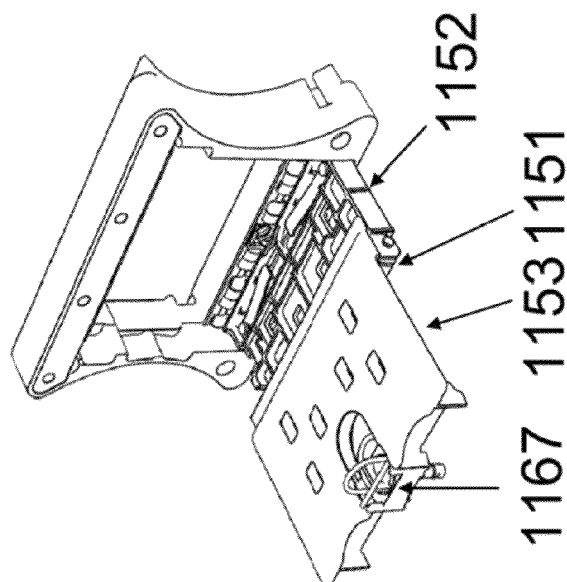


Fig. 35a

Fig. 37

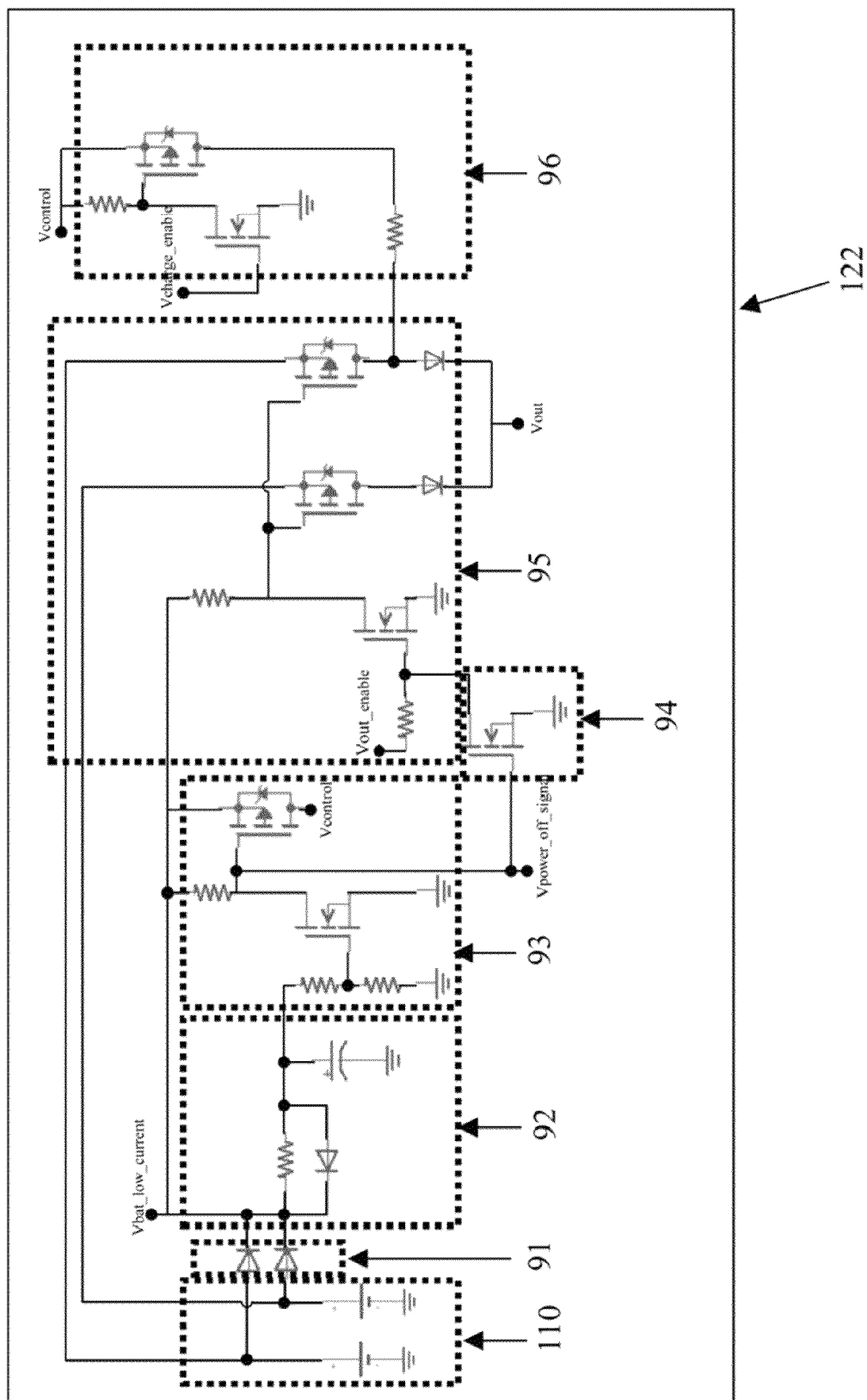
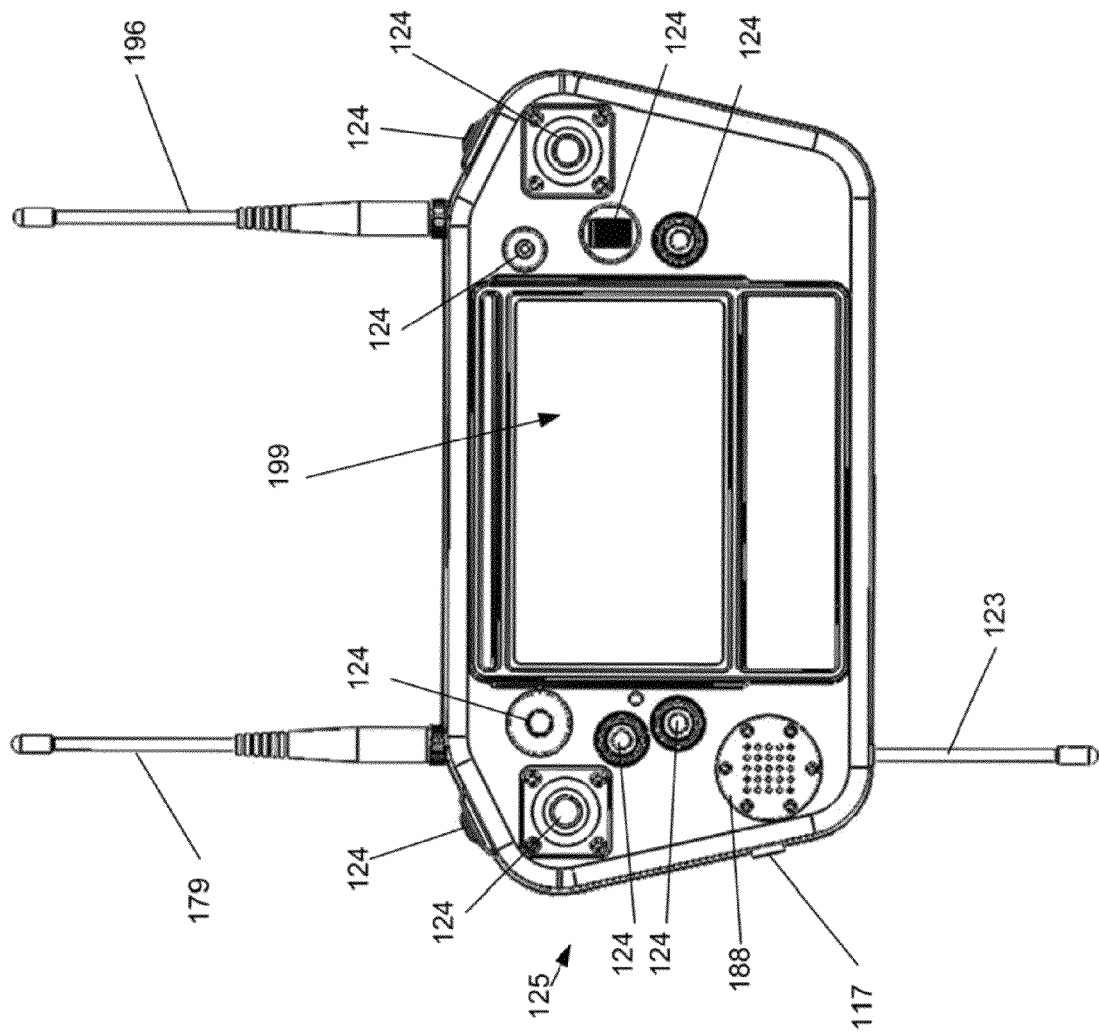


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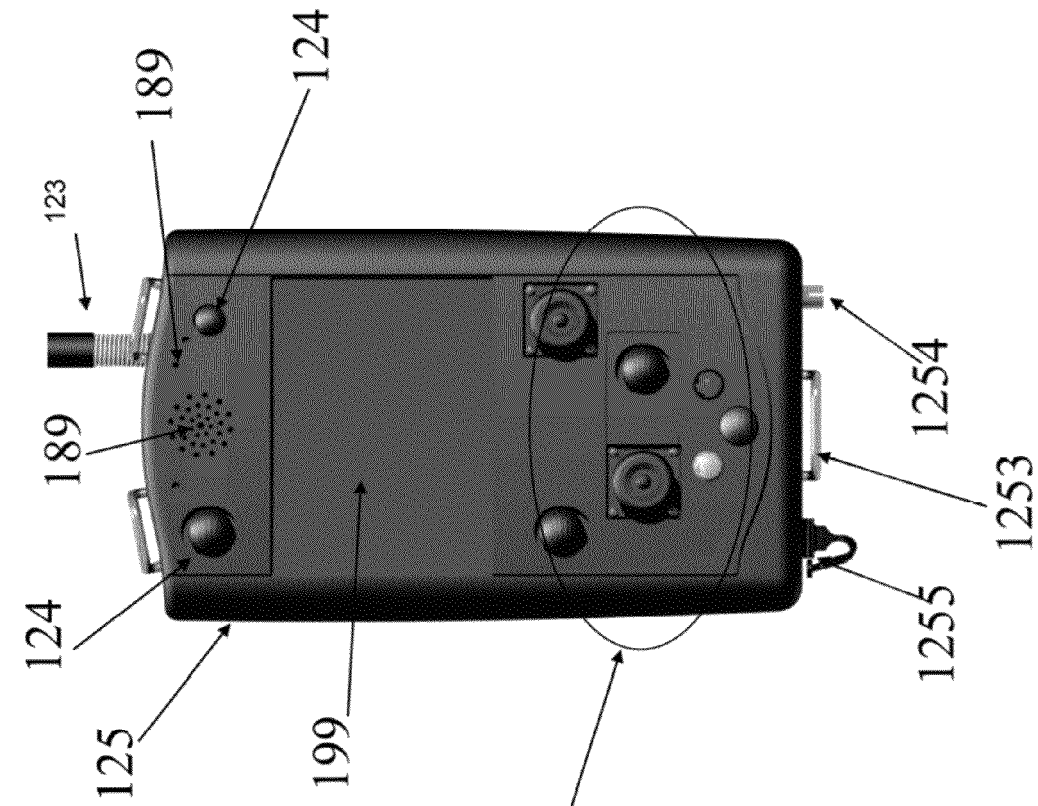


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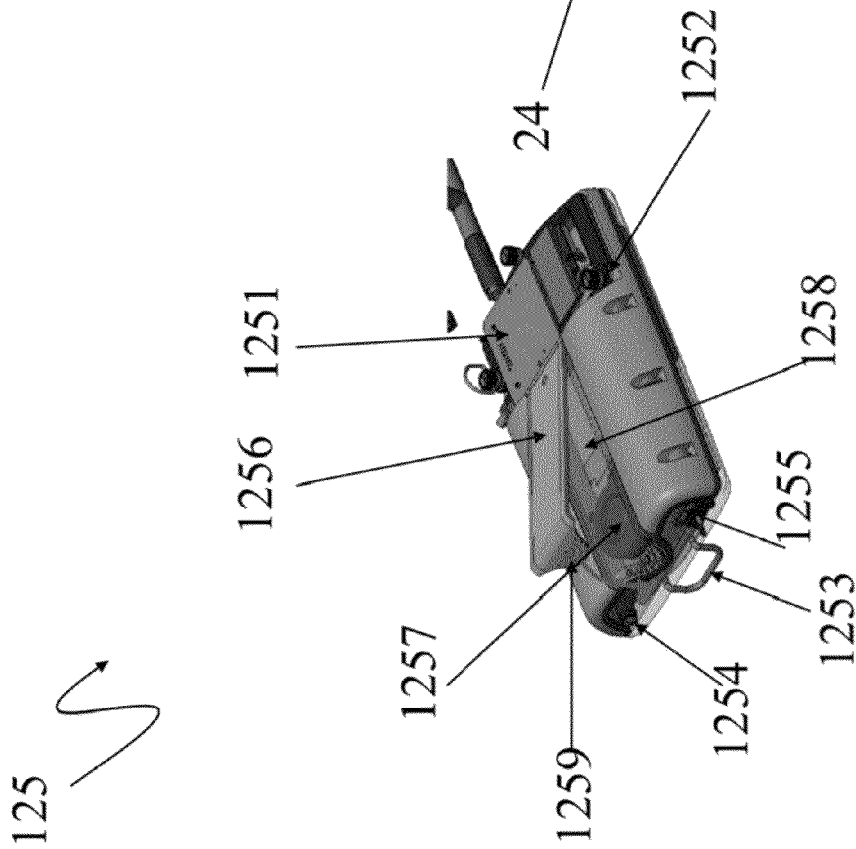


Fig. 40



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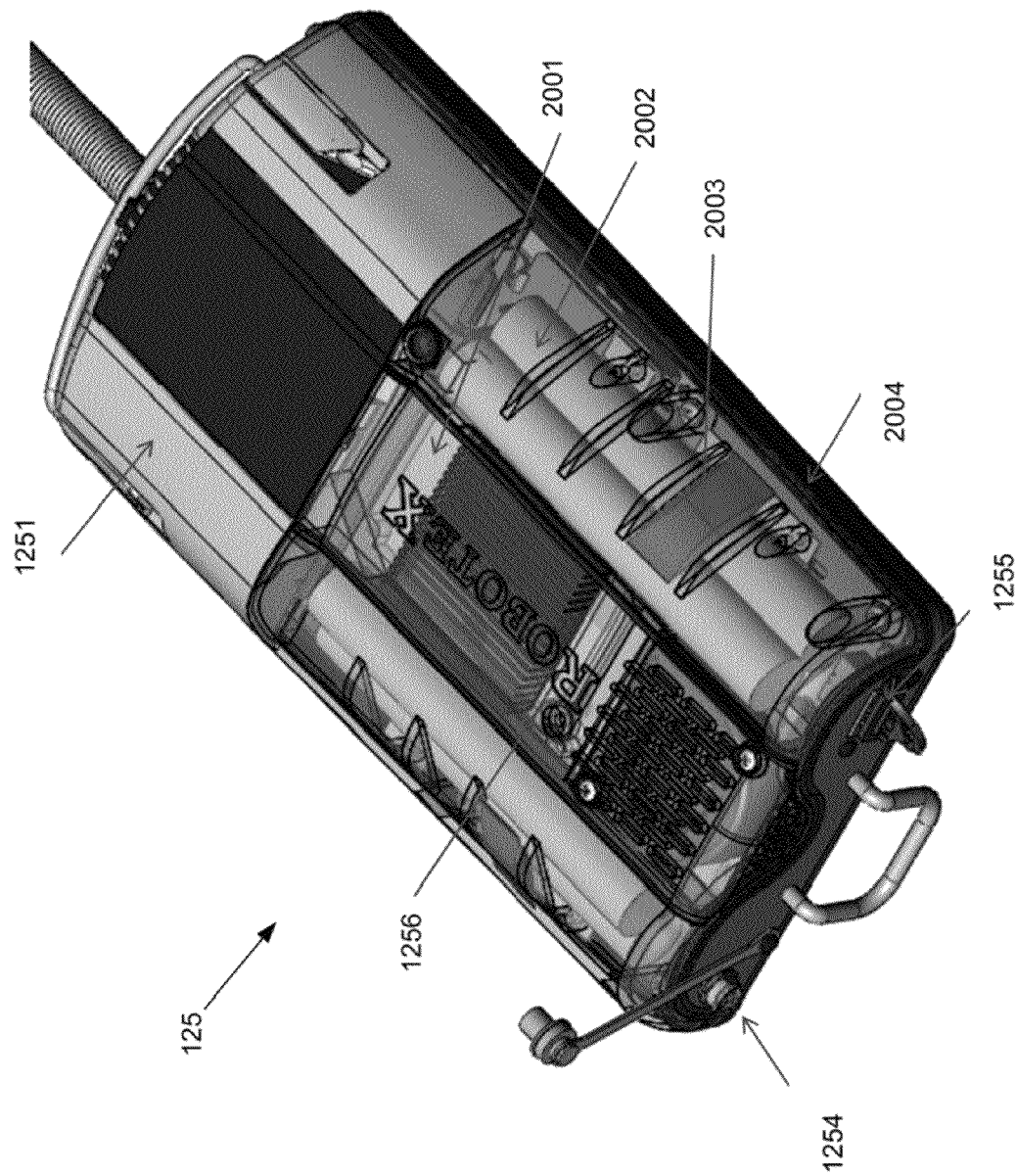


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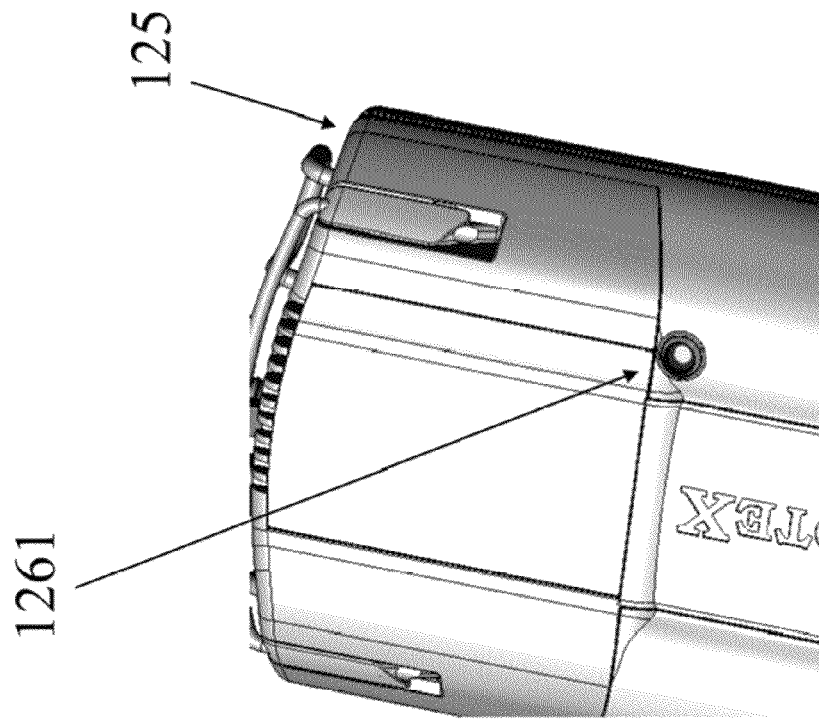


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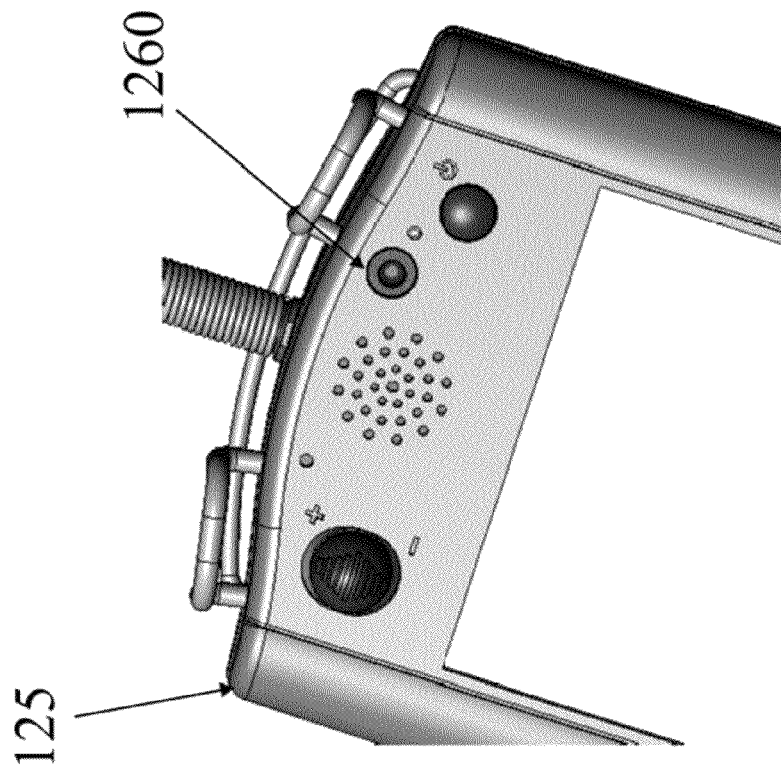


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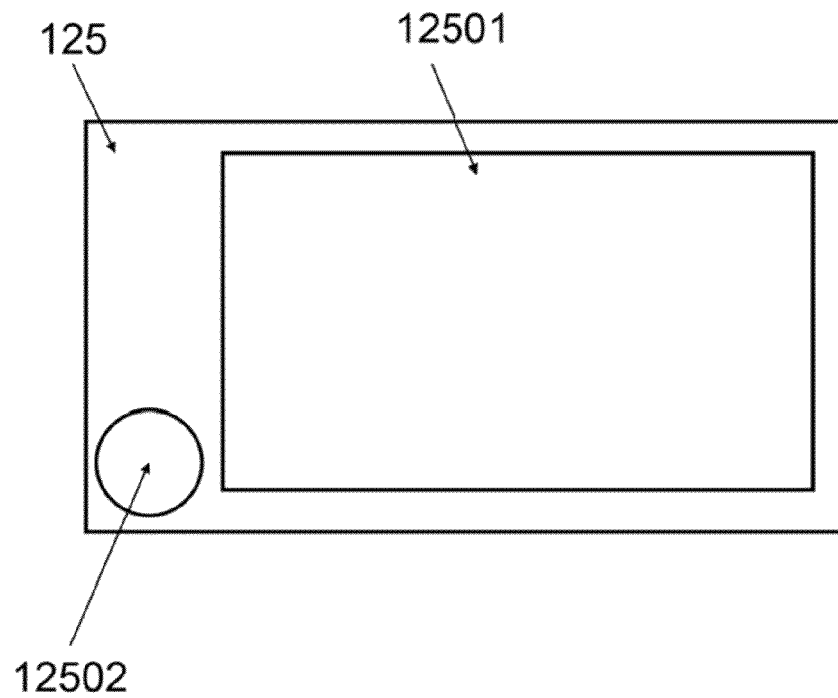


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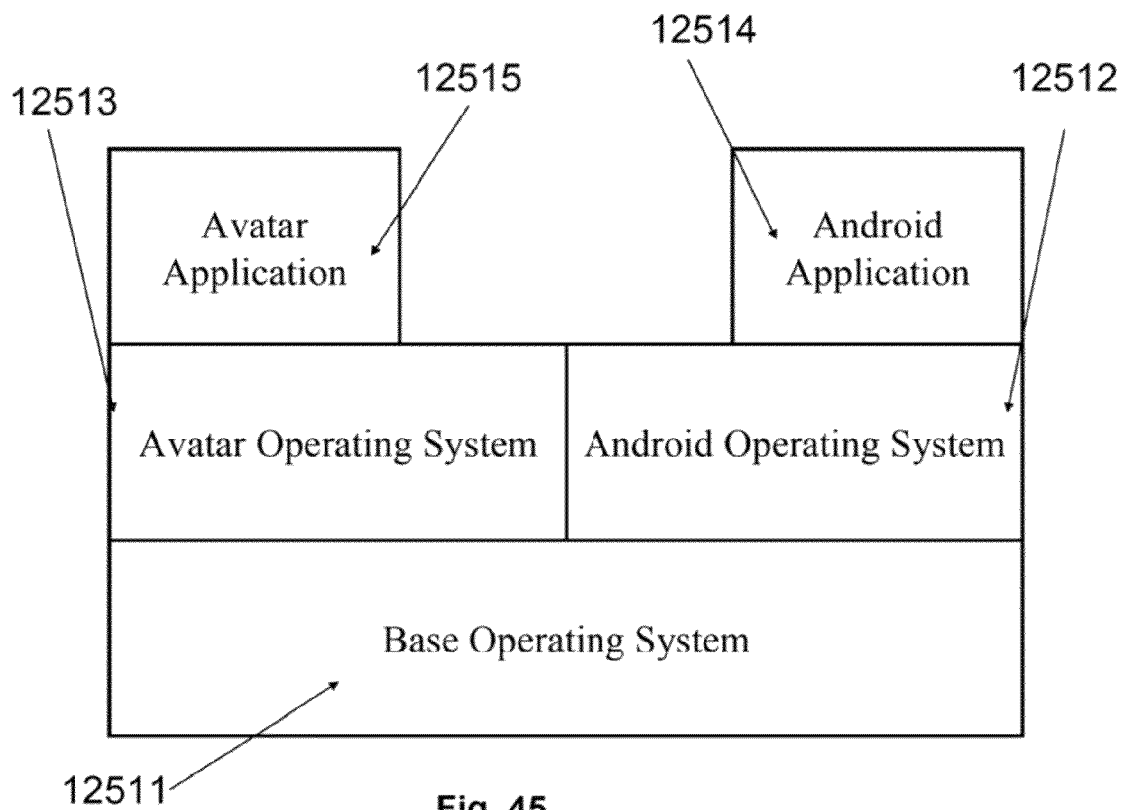


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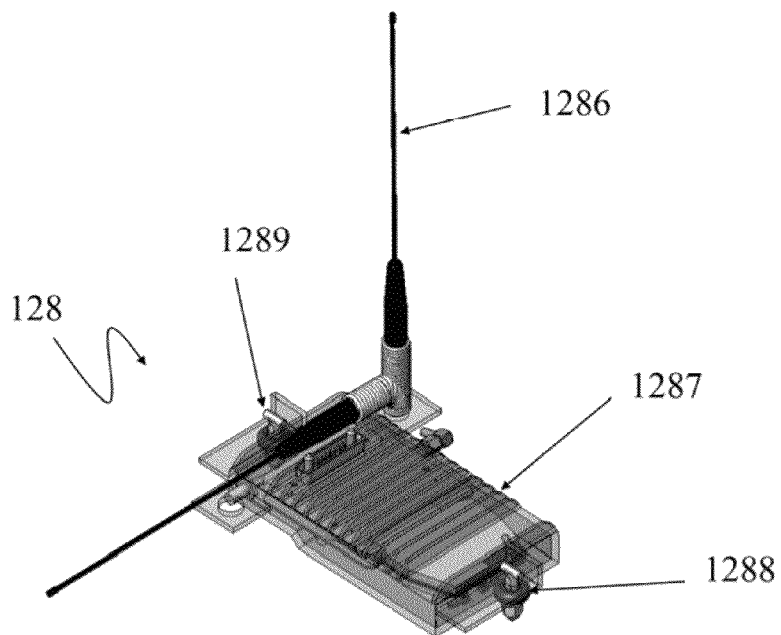


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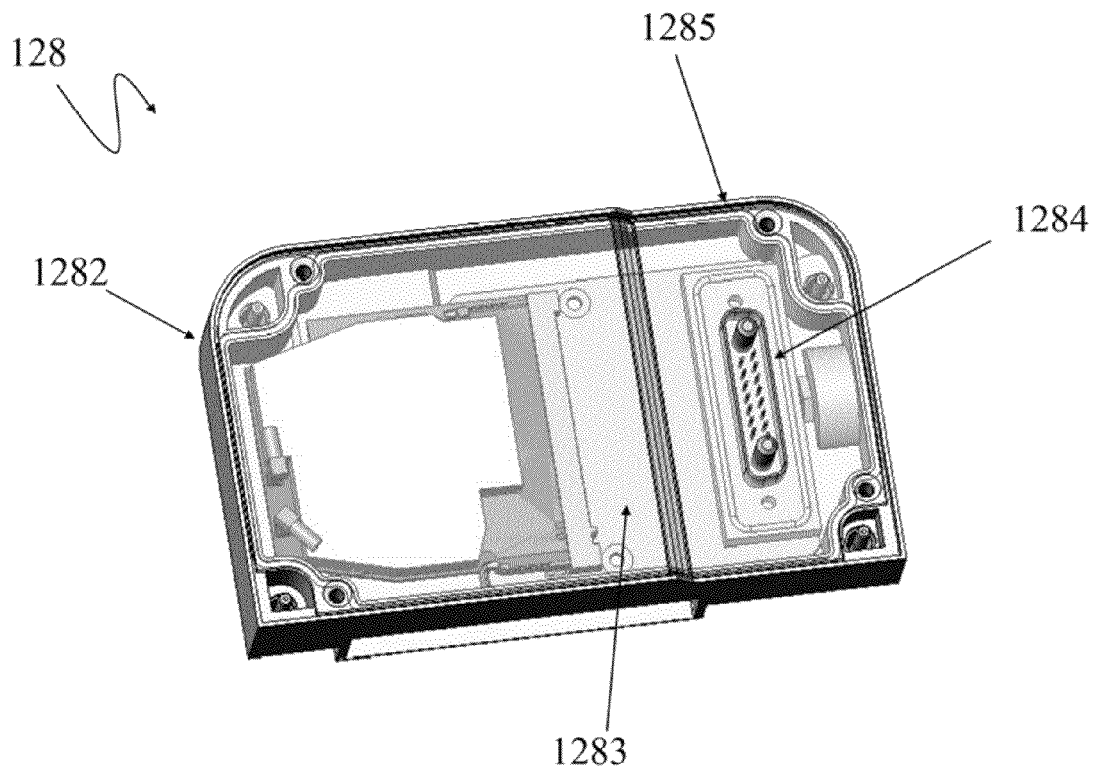


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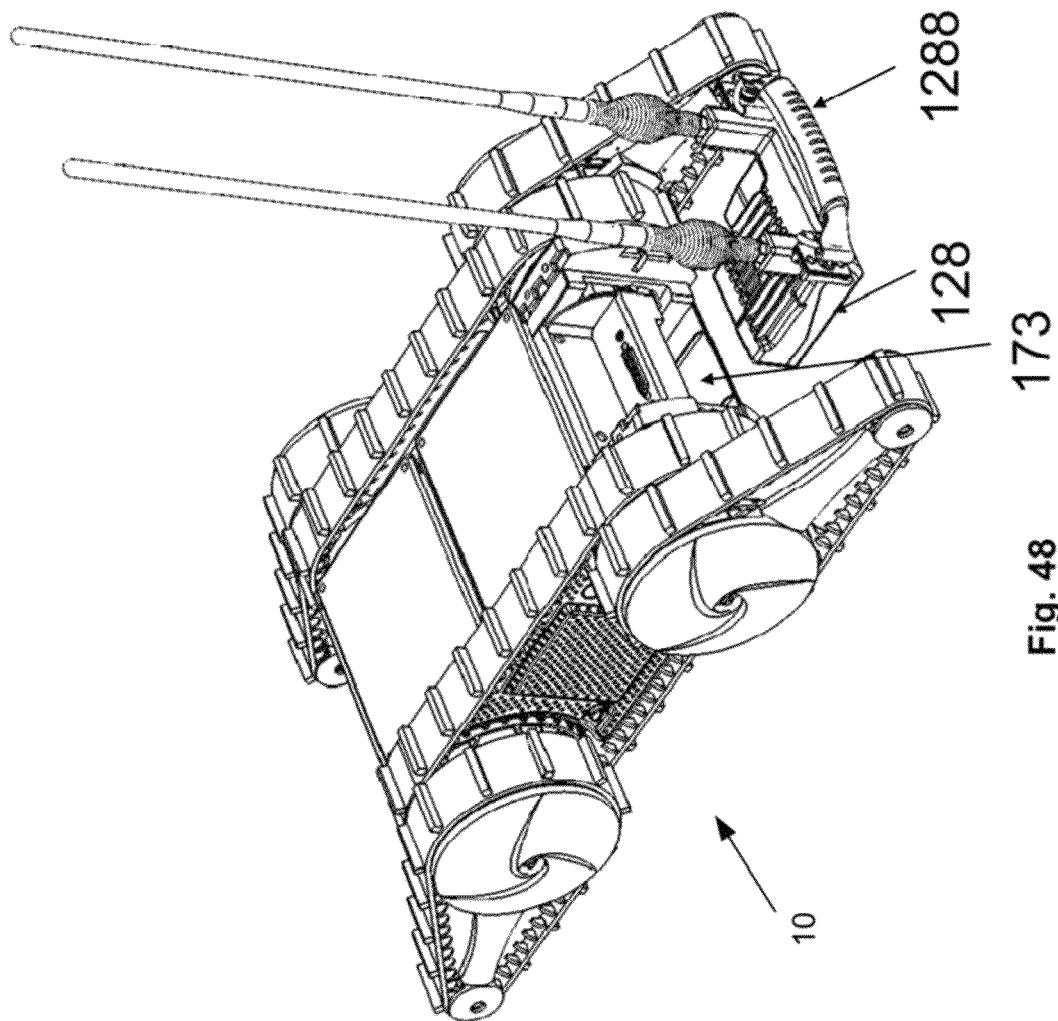


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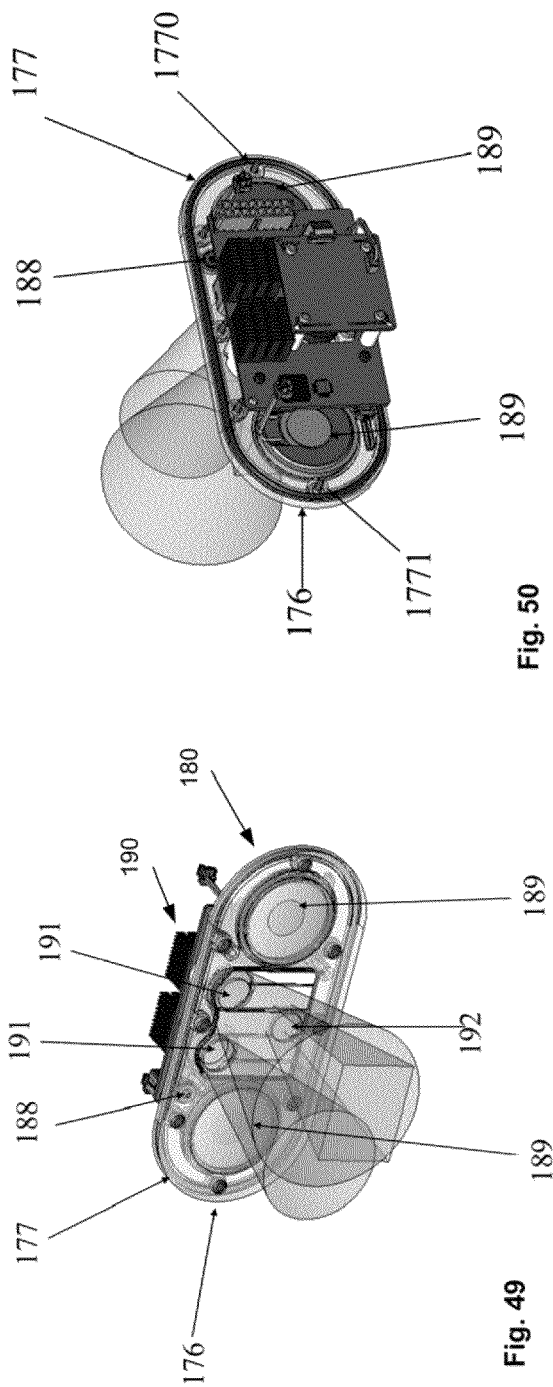


Fig. 50

Fig. 49

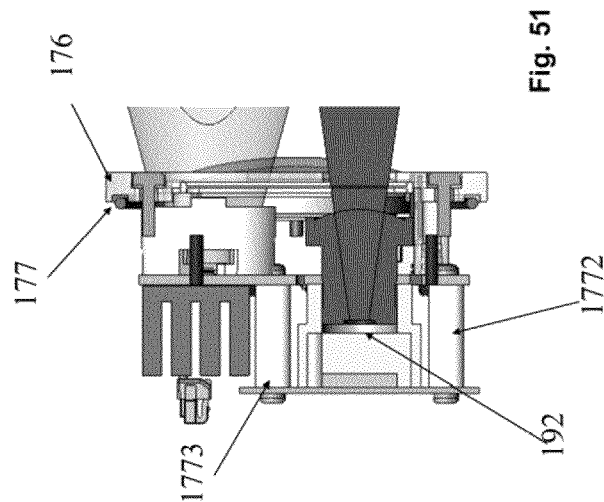
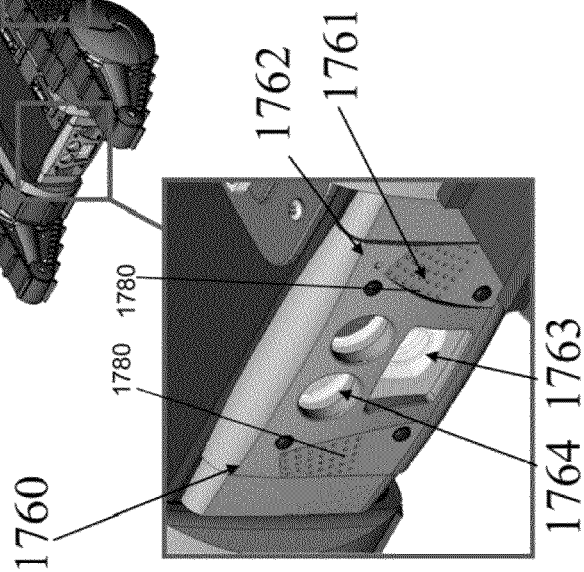
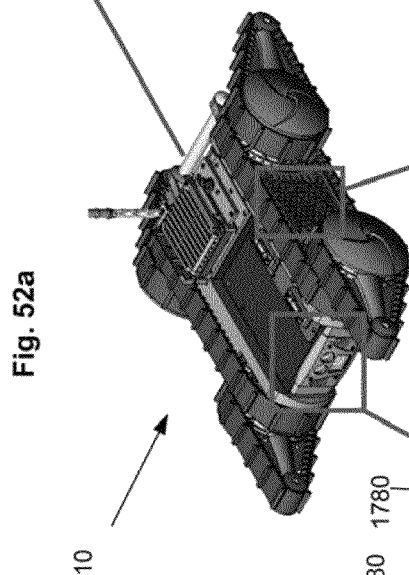
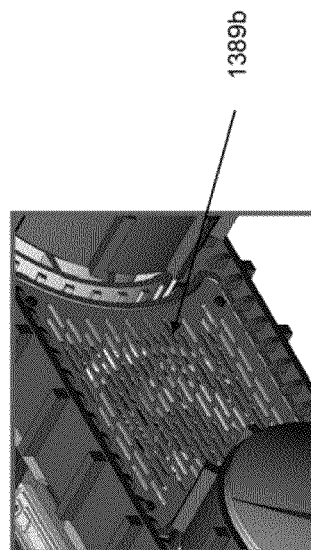
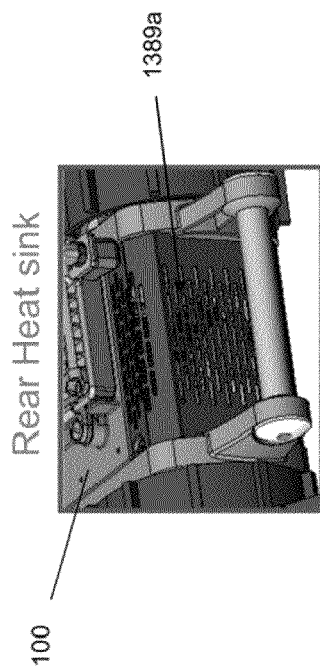


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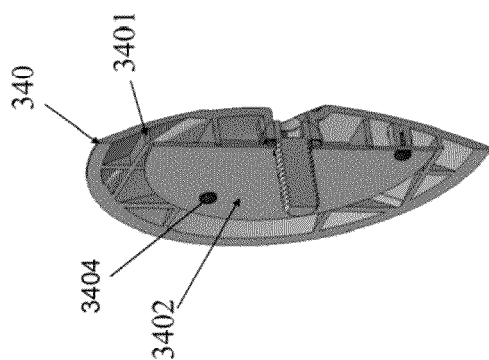


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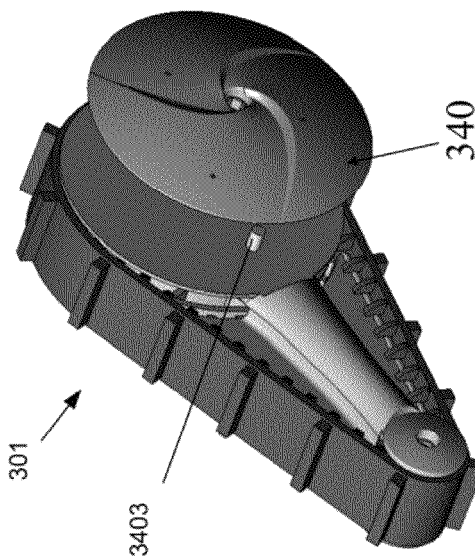


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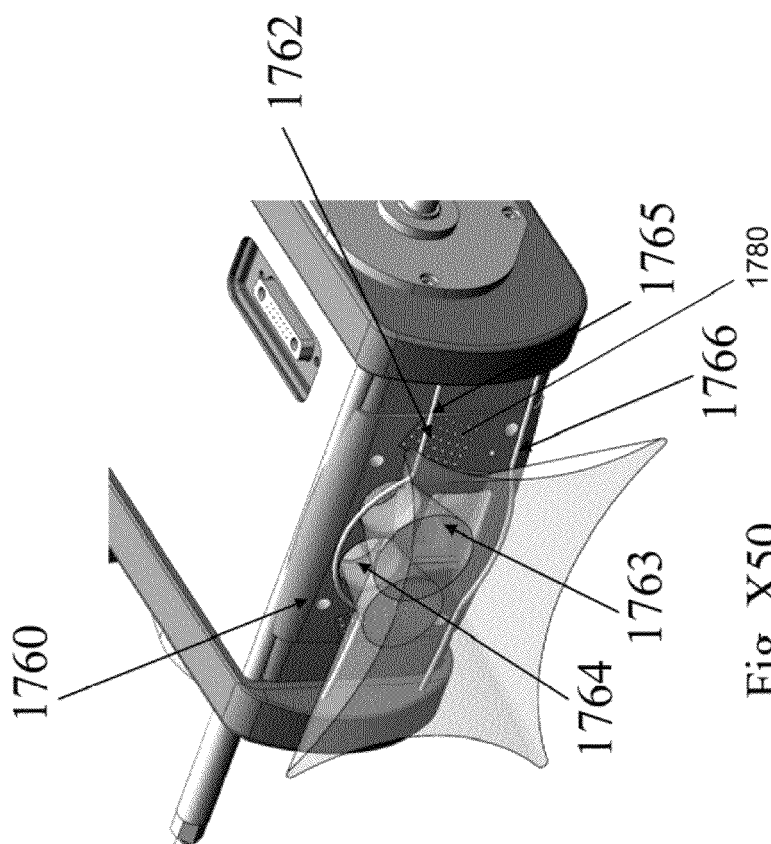


Fig. X50

Fig. 53

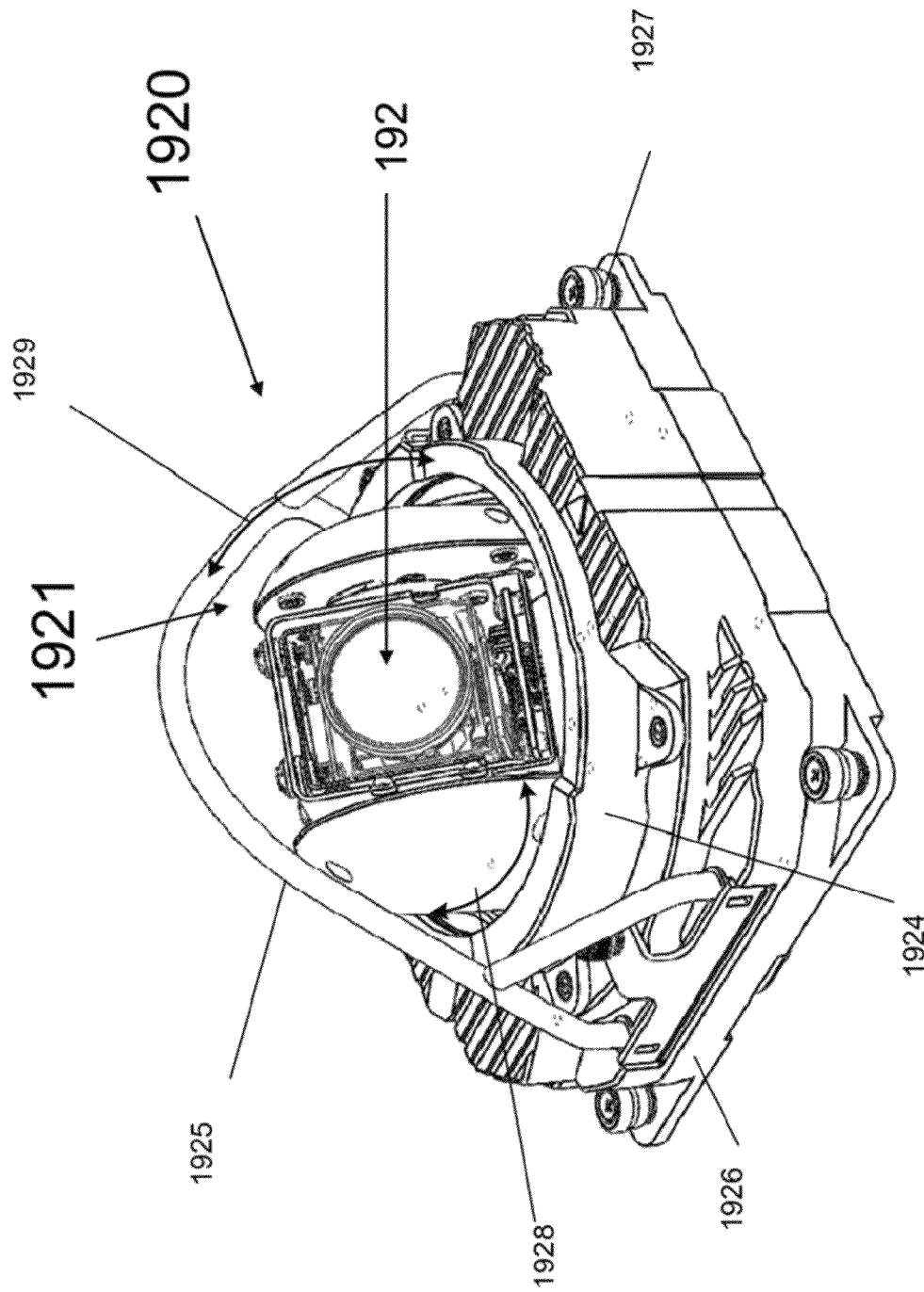


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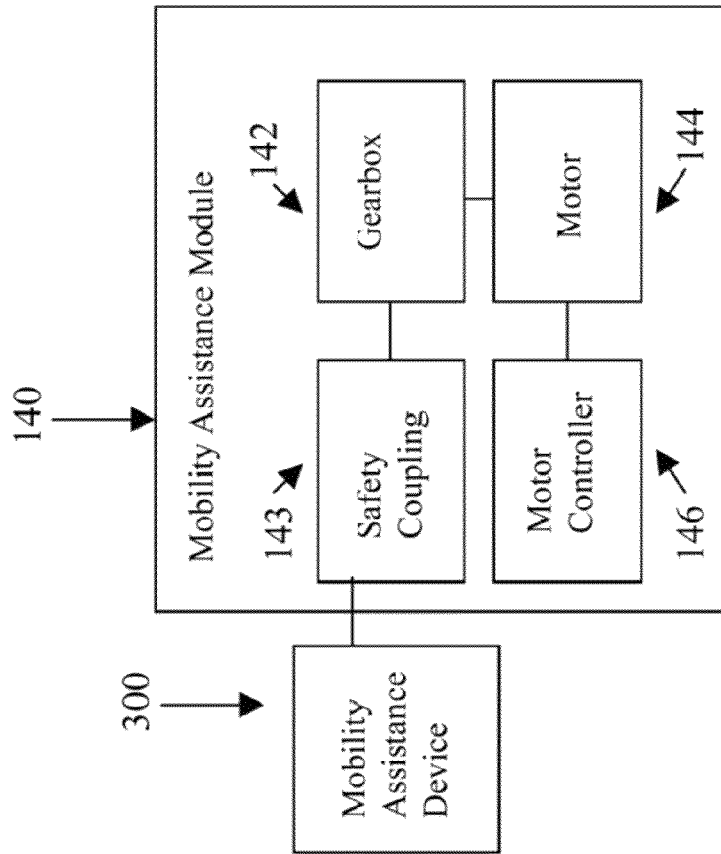


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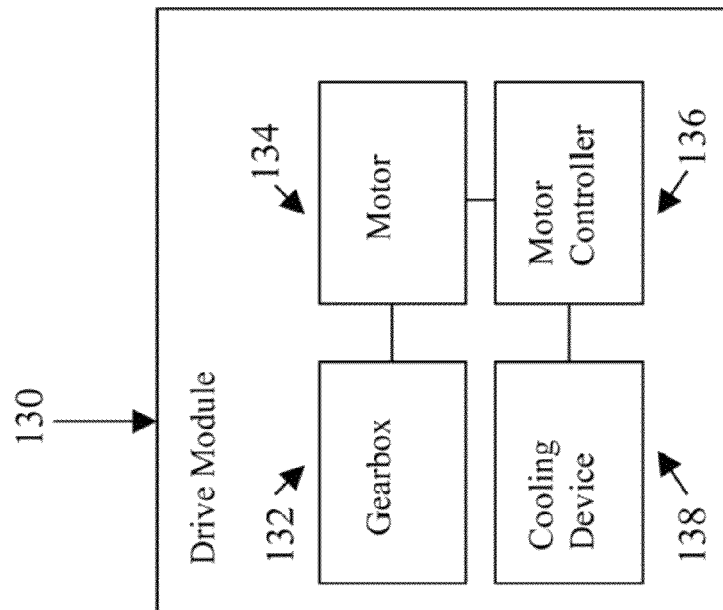


Fig. 56

Fig. 58

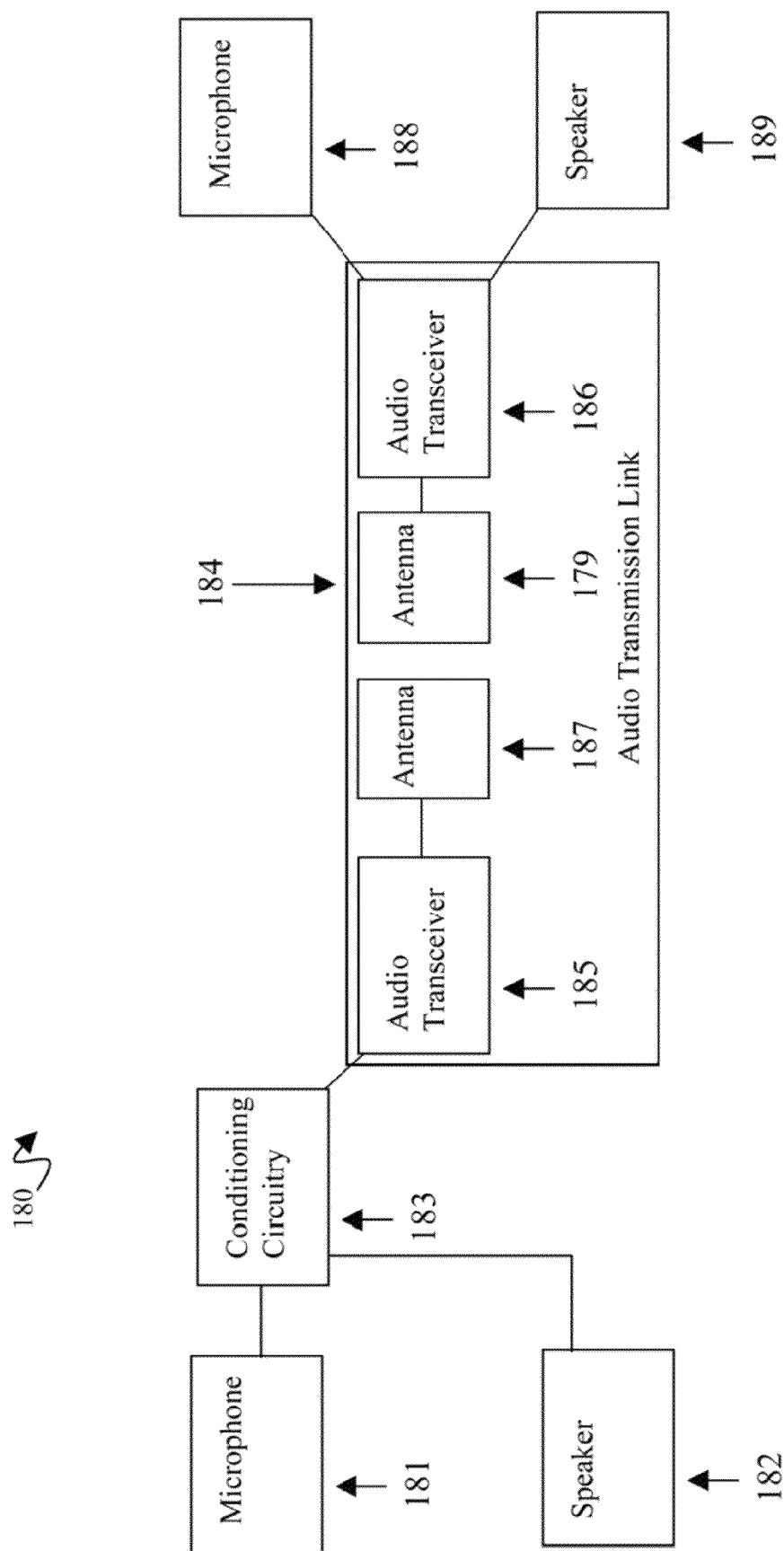
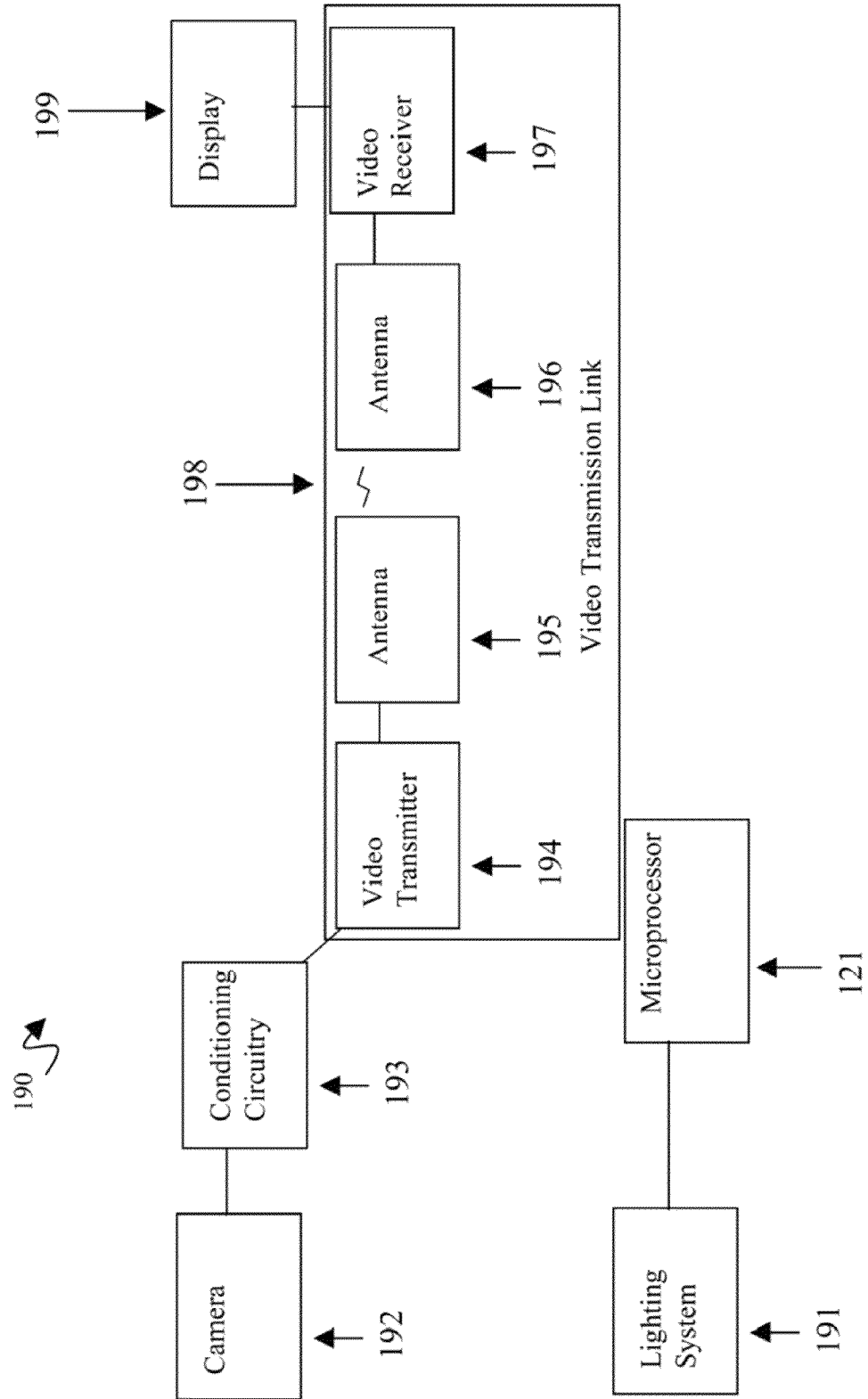
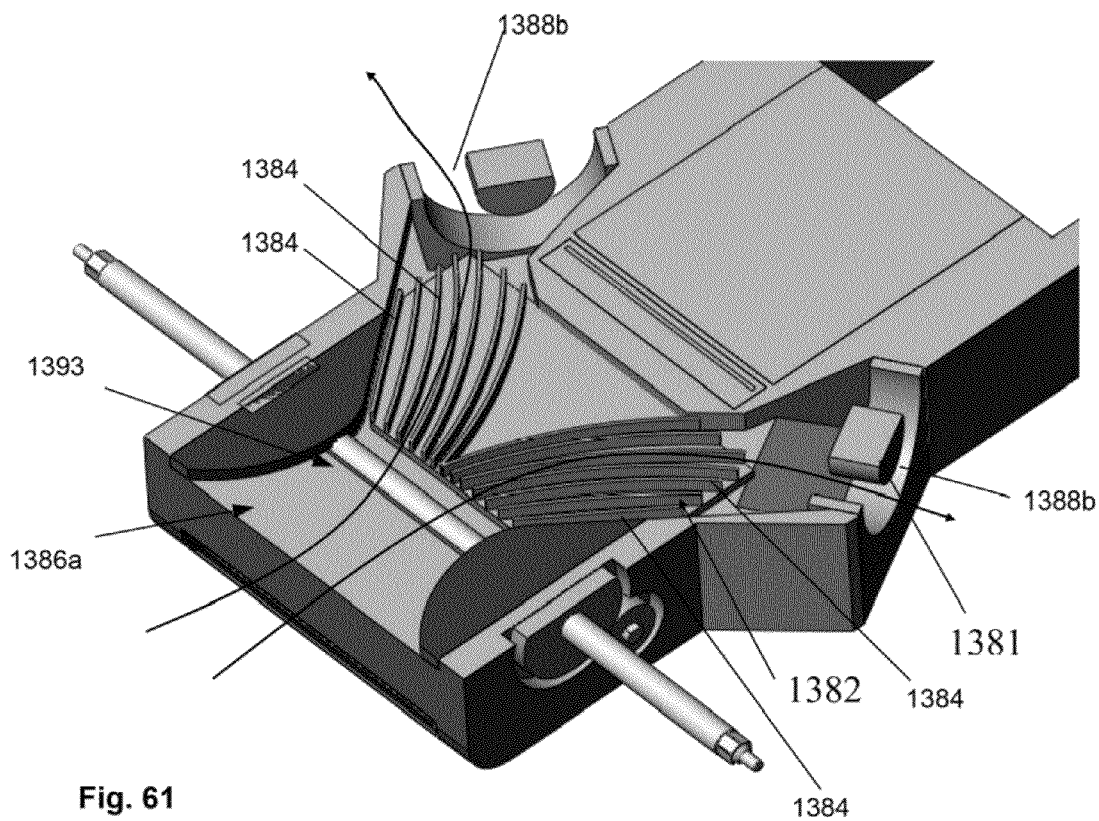
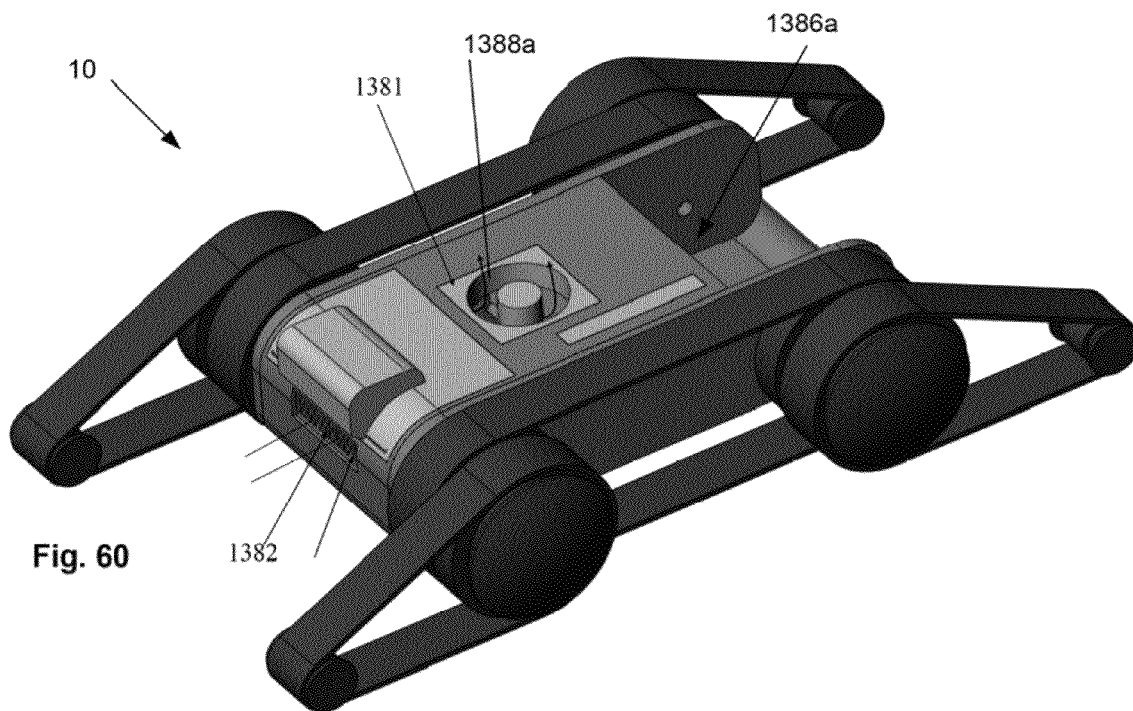
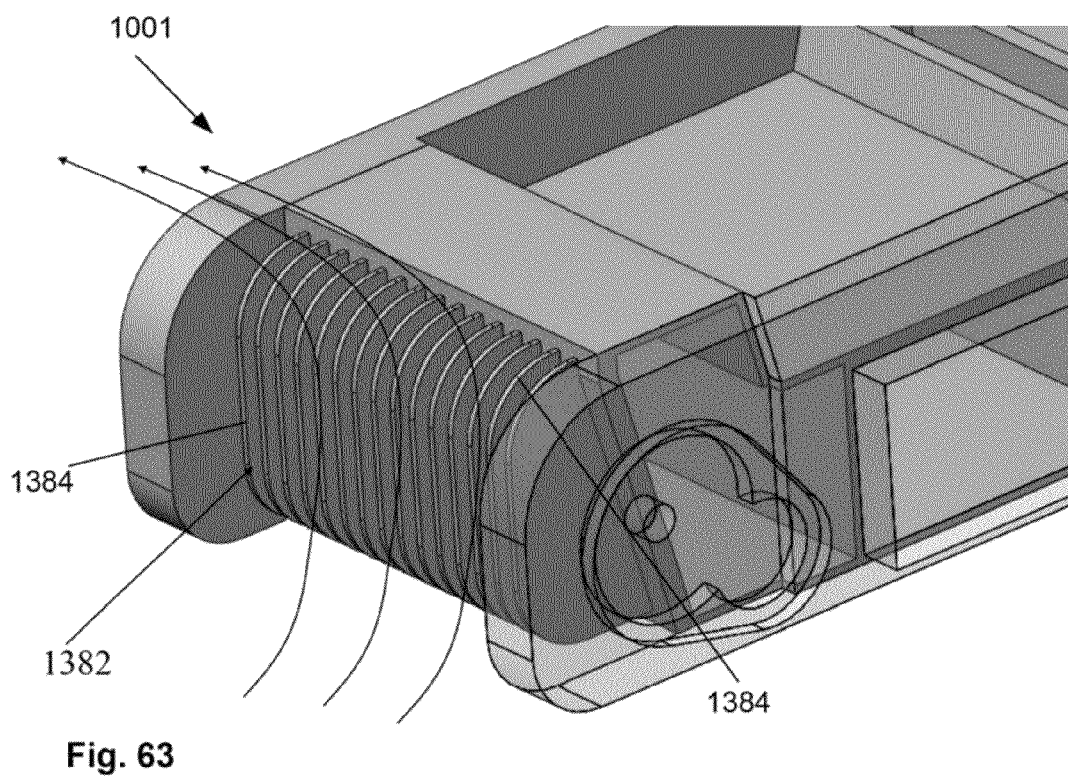
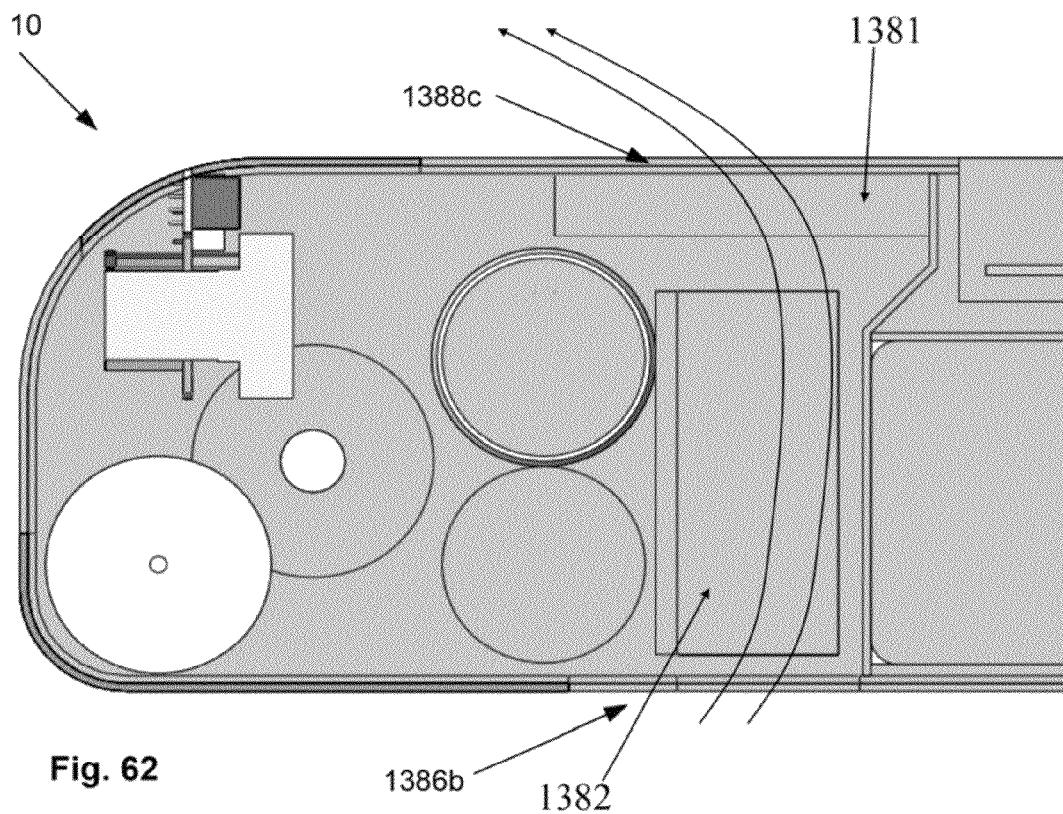


Fig. 59







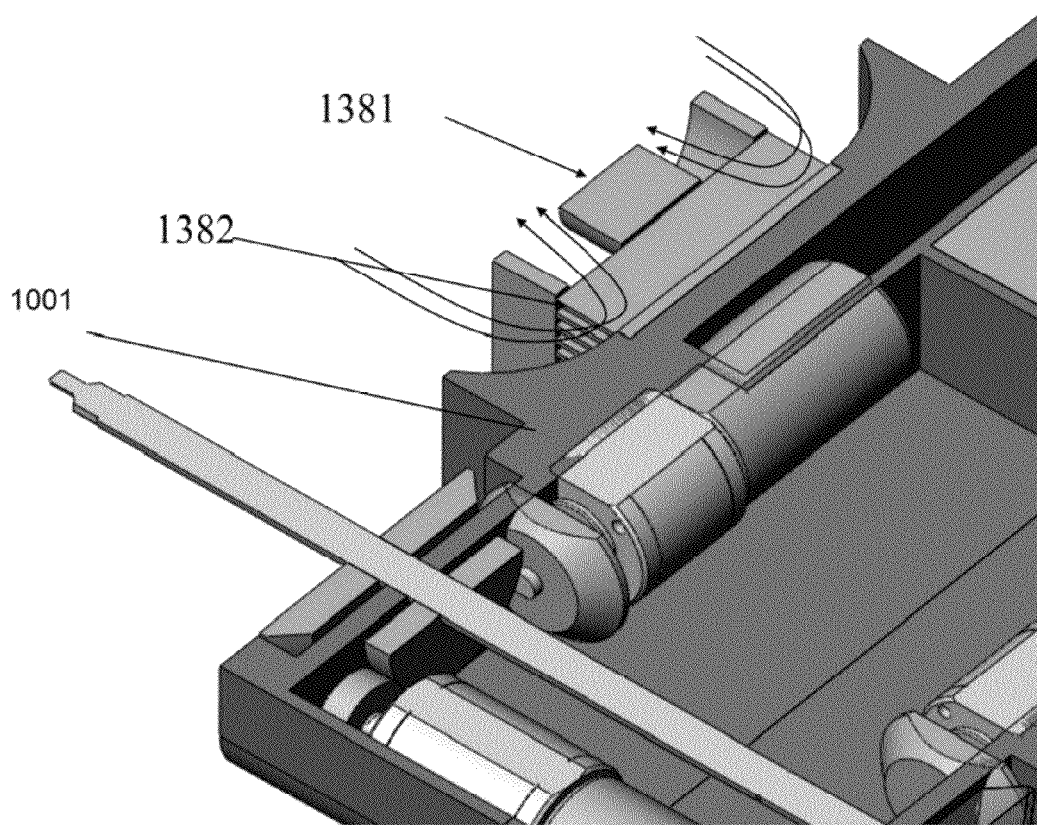


Fig. 64

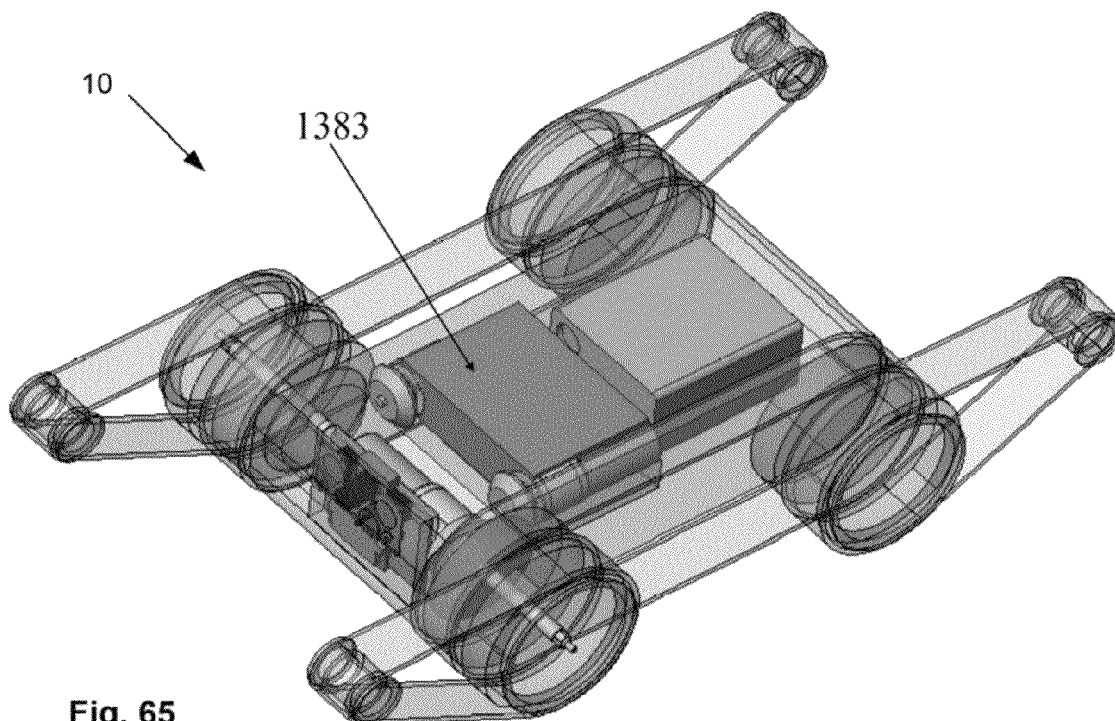


Fig. 65

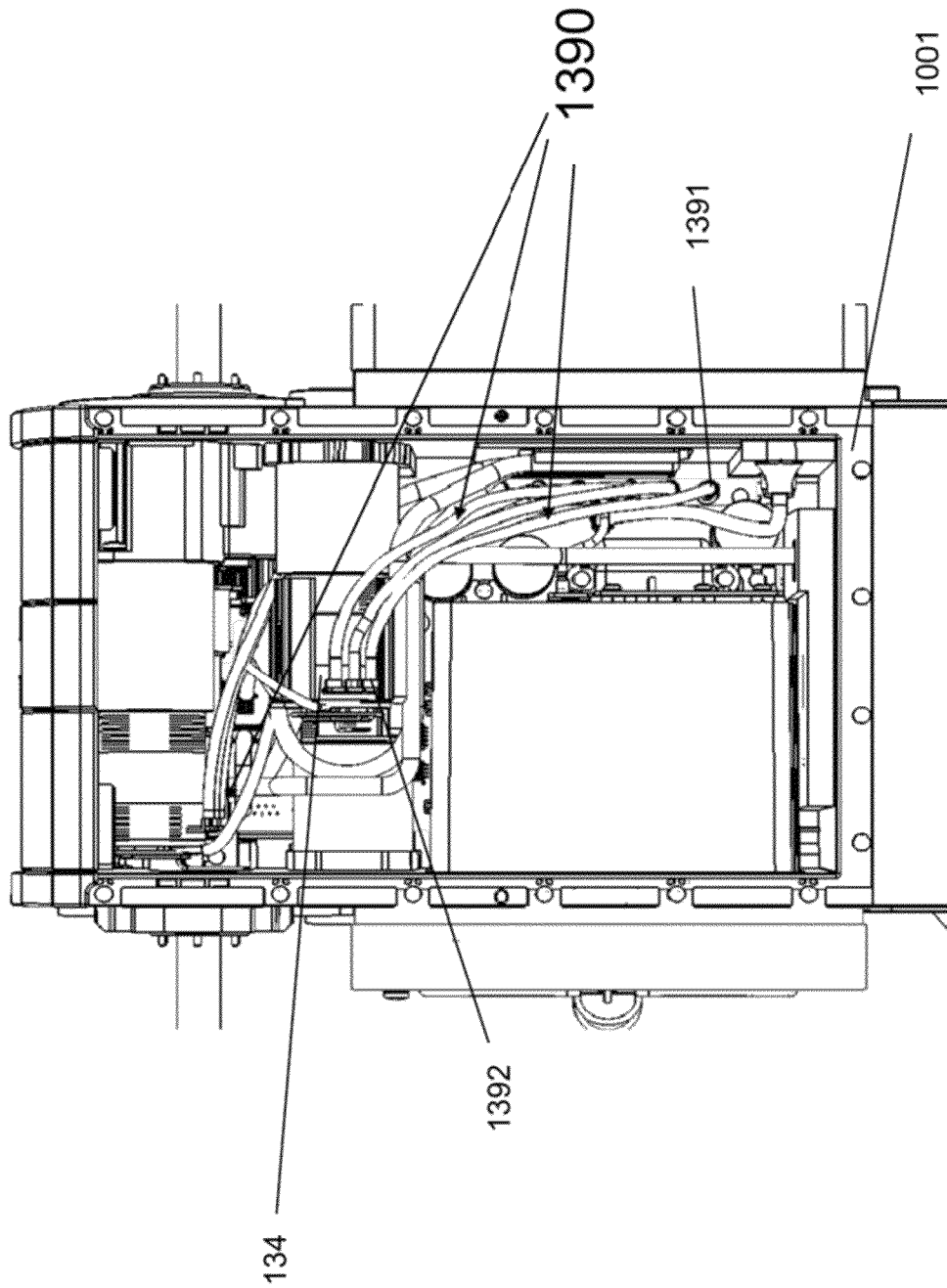
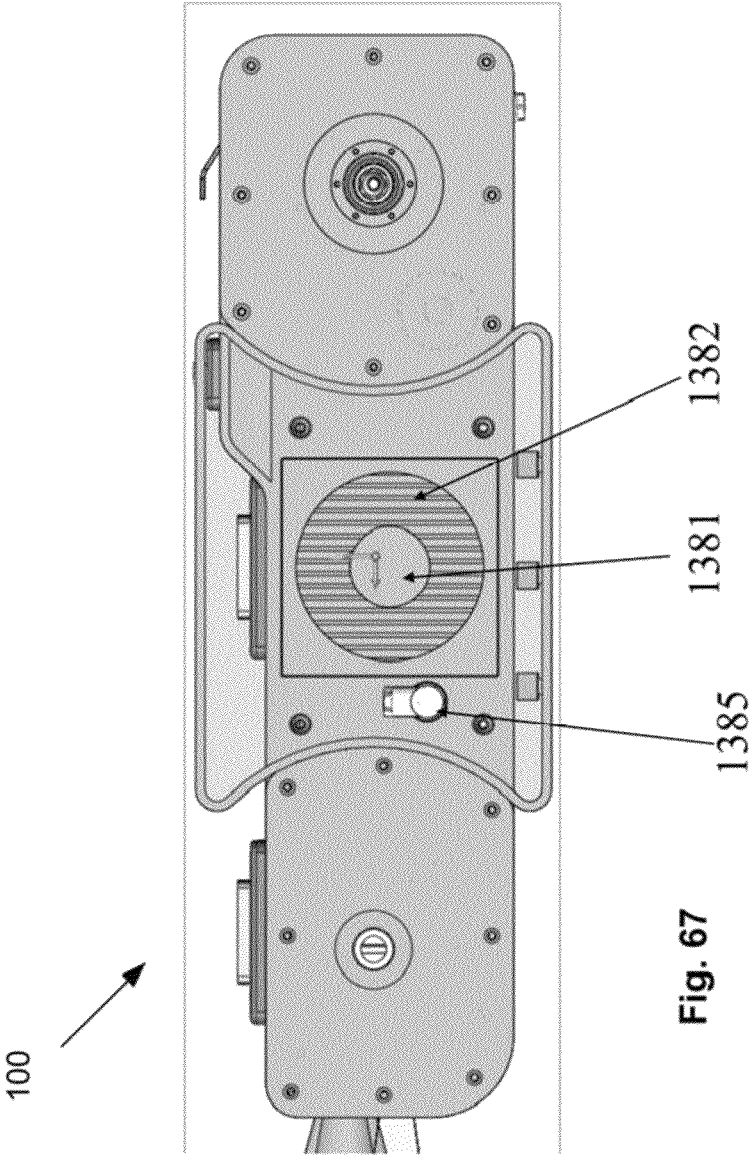


Fig. 66



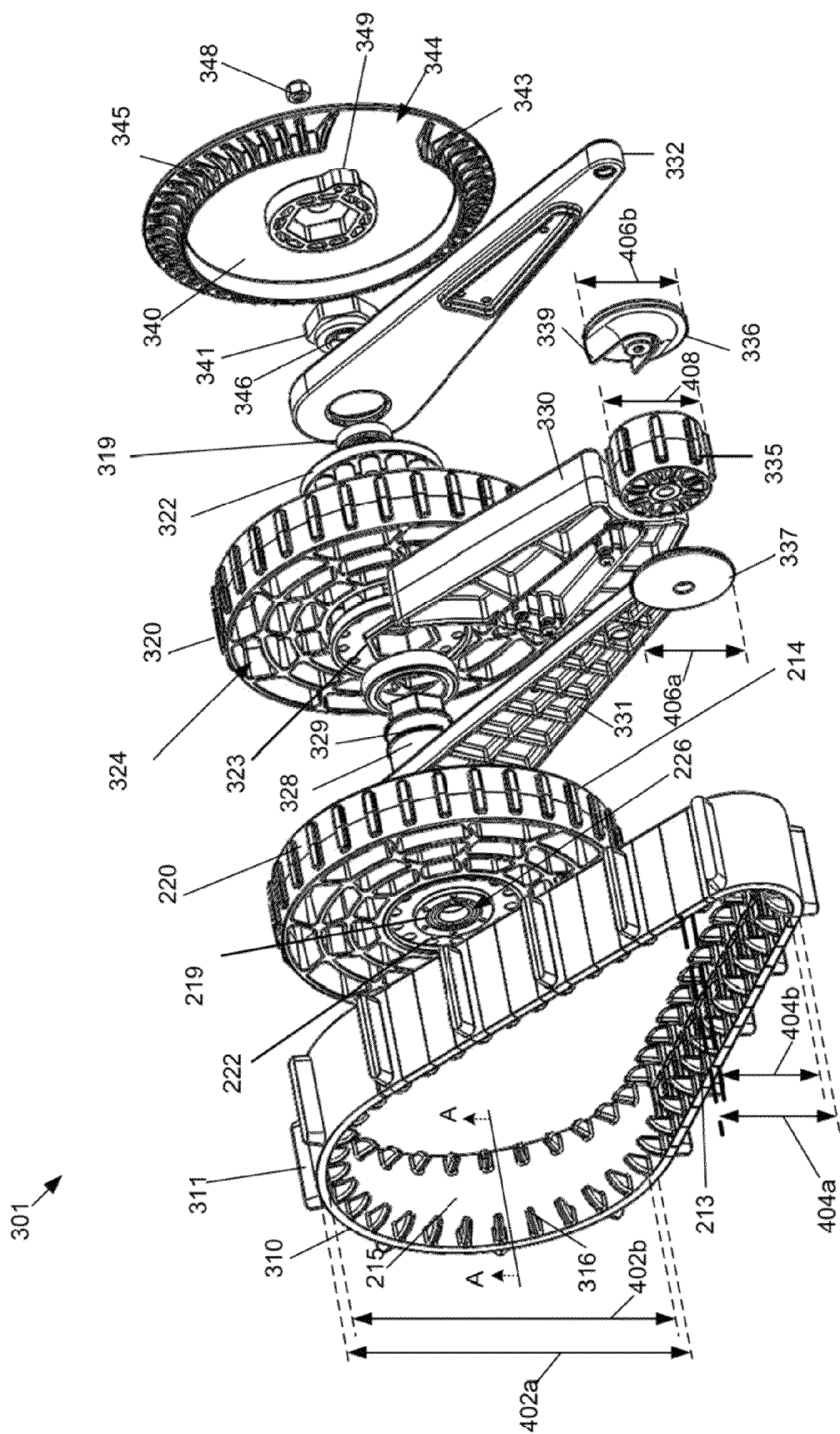


Fig. 68

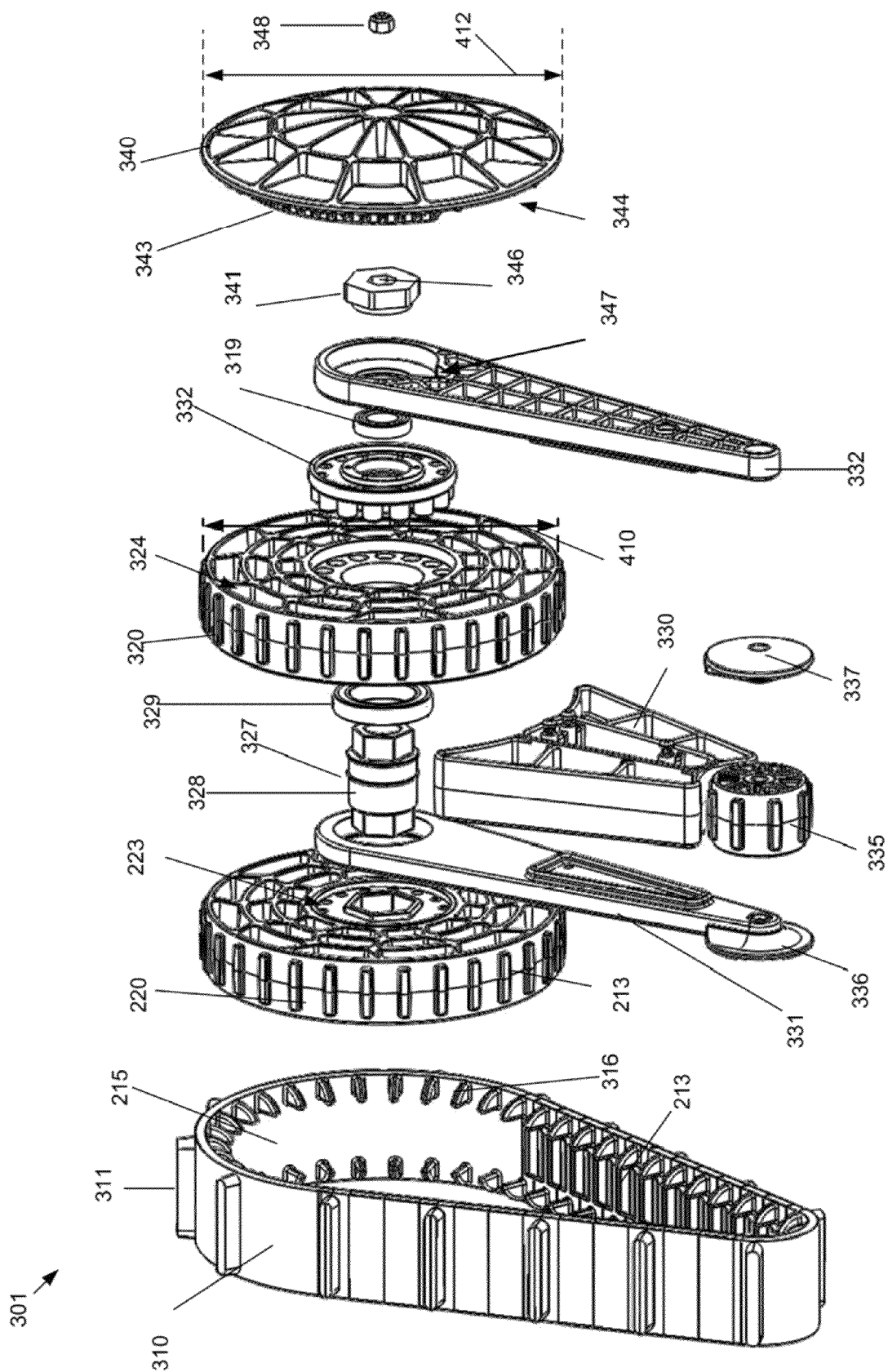


Fig. 69

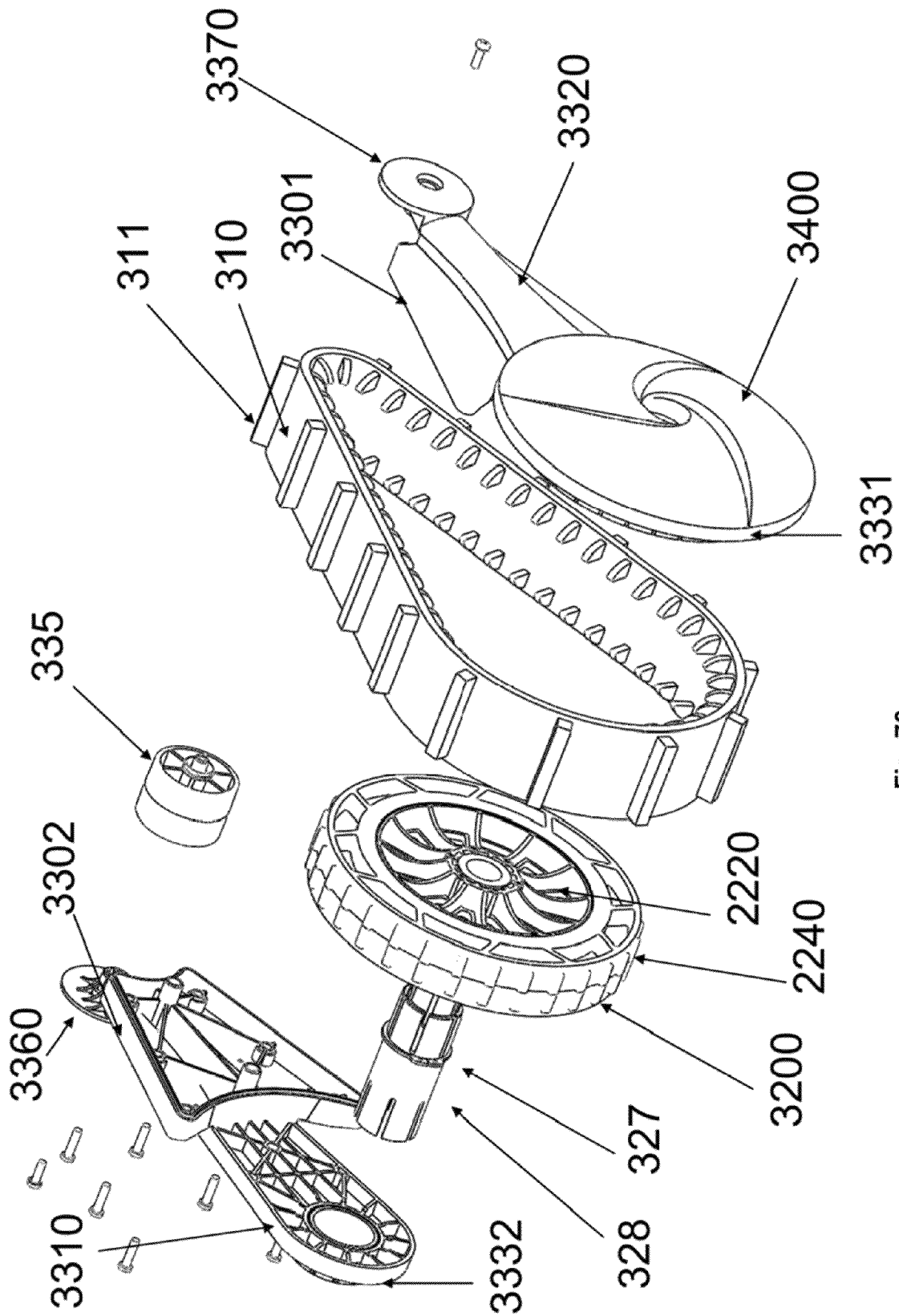


Fig. 70

Fig. 71

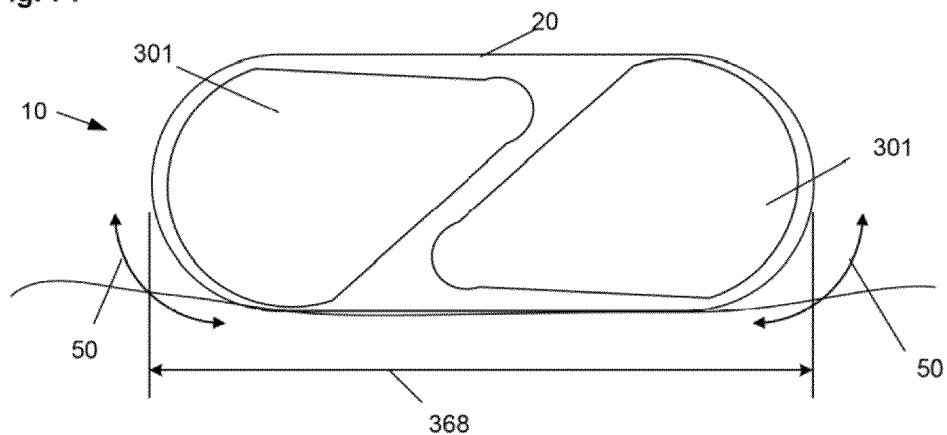


Fig. 72

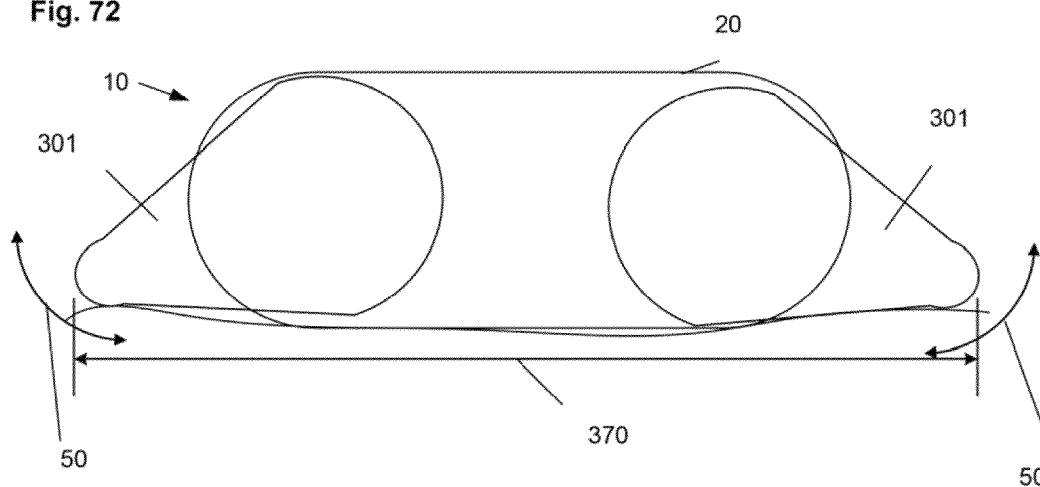
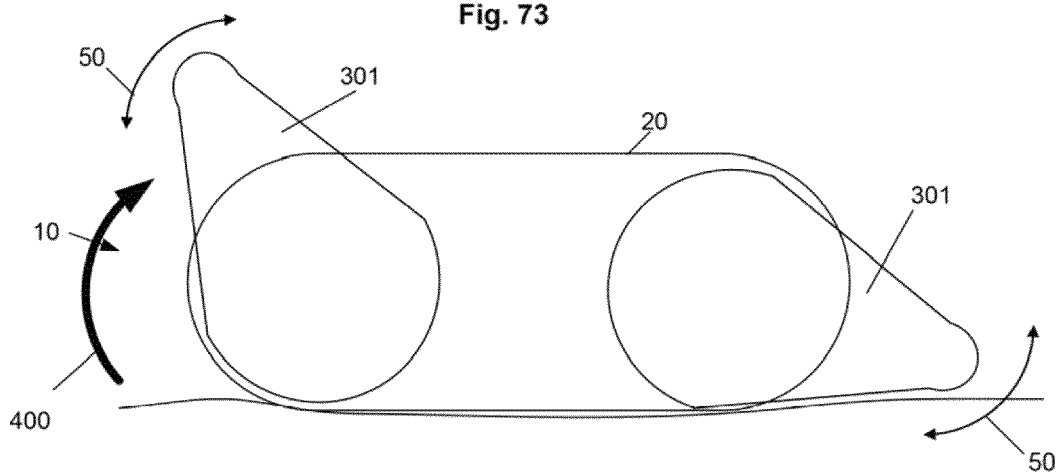


Fig. 73



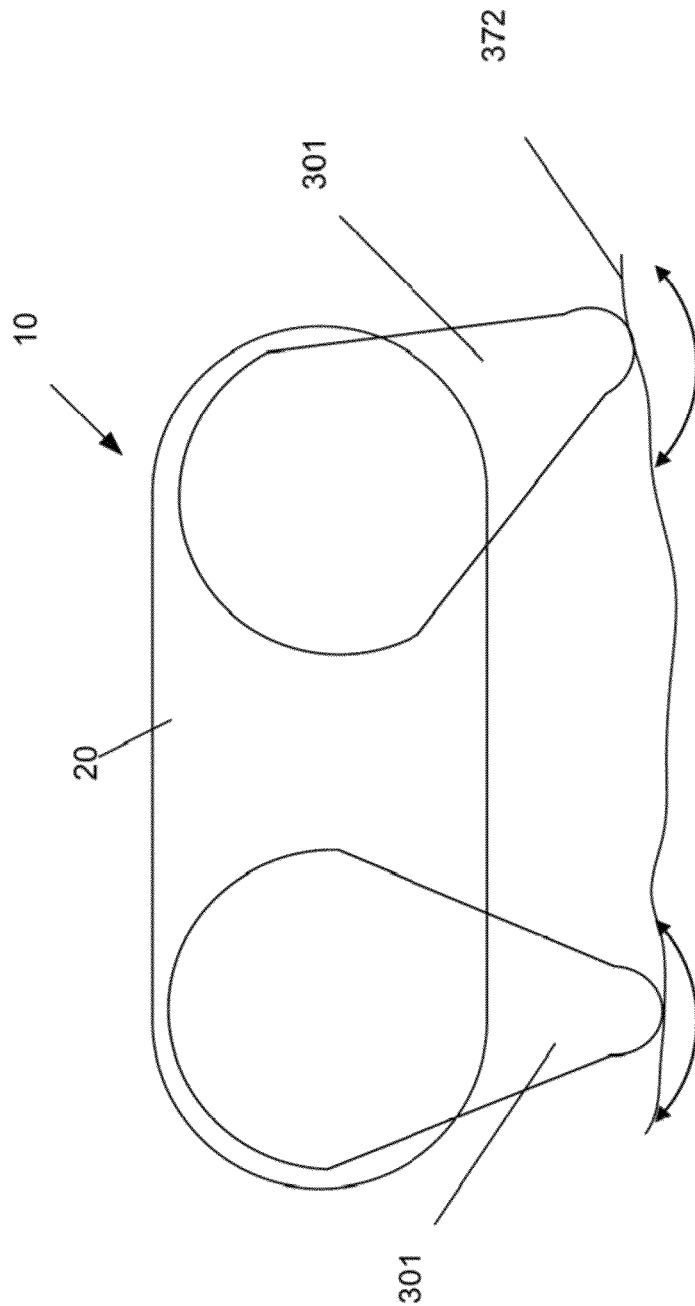


Fig. 74

ROBOTIC SYSTEM AND METHODS OF USE**CROSS-REFERENCE TO RELATED APPLICATION**

This application claims priority to U.S. Provisional Application No. 61/586,238 filed 13 Jan. 2012, which is incorporated by reference herein in its entirety.

BACKGROUND**1. Technical Field**

This invention relates generally to the robotics field, and more specifically to a new and useful robotic system in the robotics field.

2. Summary of the Art

Ground-based remote-controlled robotic systems exist for a number of purposes. Unmanned Ground Vehicles (UGV), such as Soldier UGVs (SUGVs) are small, remotely controlled robotic systems, often purposed for military use. The UGVs can provide remote surveillance images and sensed information. UGVs can be tele-operated in an area local to a controlling dismounted soldier, and be transported to the operational area with dismounted soldiers as stowage. The UGVs operate in rural and urban terrain, and often are needed to climb stairs, pass through doorways, operation in subterranean structures, and traverse rubble or other obstacles.

Domestic police, including Special Weapons and Tactics (SWAT) Teams, use UGVs for domestic policing, including performing “hard clears” or other high risk actions when human health or life might be at stake.

Remote control (RC) vehicles are also used for civilian entertainment, such as remote control hobbyist cars and tanks. Such vehicles are often insufficiently robust for purposes other than racing or entertainment, and rarely have tooling or payloads to accomplish task other than mobility.

Industrial robots are used to access hazardous or cramped areas for industrial purposes or scientific research. For example, remote-controlled industrial robots can be used to access and work in areas with extreme pressures, temperatures, radioactive radiation, high voltage, toxic gasses or a lack of breathable air.

All of the aforementioned robotic systems desire improved performance characteristics, for example more stabilized mobility, self-cleaning tracks, increased torque delivery to the ground, reliable control and data collection transmission, and dimensionally small packaging for transport despite a potentially larger area occupied during mobility of the robot.

SUMMARY OF THE INVENTION

A robotic system and method of using the same are disclosed. The robotic system can have one or more tracks that are driven by track drive pulleys. The track pulleys can be driven by a motor. The robotic system can have track guides, track pulley caps, and flipper pulley caps. The robotic system can have sideplates that are larger (i.e., can extend further) than the track inner diameter and the inner nubs on the tracks.

The tracks can be flexible with or without reinforcing cabling. The track can be fed over the track drive pulleys. The track can resiliently expand and/or the pulley can resiliently contract when debris is introduced to the space between the track and the drive pulley. This can squeeze larger debris out of the track. Smaller debris can be carried through the track until the debris reaches the top (or bottom, depending on the direction of the pulley) of the drive pulley, causing the debris to fall out of the space between the track and the pulley and

return to the environment. In the case that larger debris cannot be squeezed out from between the track and pulley, the flexible pulley can deform and pass the debris through the space between the track and pulley, and then dump or release the debris when the debris reaches the top (or bottom, depending on the direction of the pulley) of the pulley.

The track and/or pulley can instead or in addition be rollers.

The sideplates and the pulley end caps can laterally retain the track, for example when the trapped debris causes the track to expand to the extent that the track would pop off of the pulley when turning in debris. The lateral ribs on the drive pulley can be long enough to engage the track either directly, or through a layer of debris. The track can not dislodge from the pulley or rollers, for example even when performing a zero turning radius maneuver under heavy load, in a dirty, debris-filled environment. The amount of allowable track expansion (stretching with debris) can be related to the extent to which the end caps and side plates extend beyond the inner diameter of the track as the track rotates around the drive pulleys and rollers, and to the protrusion distance of the drive pulley rib relative to the outer diameter of the drive pulley.

A robotic system that can have a self-cleaning track drive system is disclosed. The system can have a body, and the track drive system configured to move the body. The track drive system can have a one pulley and a track. The pulley can be configured to form at least one pocket between the inner track surface and the outer pulley surface when a foreign object is introduced between the pulley and the track, and wherein the foreign object has a maximum width of greater than about 0.2 cm.

The pulley can have a first radial rib, a second radial rib, and an outer wall. The first length of the outer wall can span between the first radial rib and the second radial rib. The first length of the outer wall can be configured to deform when the foreign object is between the first length and the track.

The track can have a modulus of elasticity from about 2,400 to about 5,600. The pulley can have a radial inner portion and a radially outer portion. The radially outer portion can be configured to deform at a greater rate than the radially inner portion when a force is applied to an outside radial surface of the pulley.

The pulley can have one, two or more support structures. The support structure can have a structural cell having two angular walls and two radial walls. The pulley can have an axis of rotation and a radially outer surface. The support structure can be between the axis of rotation and the radially outer surface of the pulley. At least one portion of the support structure can be configured to deform when a force is applied to the outside of the pulley, for example creating a pocket on the outside of the pulley where the force is applied. The support structure can have a first outer angular wall, a second angular wall, and a third inner angular wall. The second angular wall can be radially beyond the third inner angular wall. The second angular wall can be radially within the first outer angular wall.

The pulley can have a radially outer wall (e.g., an “angular” wall forming a 360° rotation around the axis of rotation). At least one portion of the radially outer wall can be configured to deform when a force is applied to the outside of the pulley, for example, forming a pocket on the outside of the pulley where the force is applied.

The pulley and the track can be configured so that a foreign object introduced between the pulley and the track is ejected by the force resulting from the resiliency of the pulley and the track. The pulley and the track can be configured so that a foreign object introduced between the pulley and the track

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can travel within the pocket between, the pulley and the track around the circumference until the track and pulley diverge.

A method of using a robotic vehicle system comprising a chassis and a track drive system comprising a pulley and a track, is disclosed. The method can include driving the track with the pulley. The method can include receiving a piece of material between the track and the pulley. The piece of material can be a loose piece of debris, for example, unattached to the track or the pulley. The piece of material can have a maximum width of greater than about 0.2 cm. The method can include moving the piece of material around the pulley to the location at which the track separates from the pulley. The method can include releasing the piece of material from between the track and the pulley.

The method of moving can include holding the piece of material between the track and the pulley. The method of holding can include resiliently deforming the track away from the pulley and against the piece of material. The method of receiving can include resiliently deforming the pulley. The pulley can include a first cell and a second cell adjacent to the first cell. The first cell can be resiliently deformed away from the track and against the piece of material. The second cell can be undeformed.

A robotic vehicle system that can have a body and a track drive system is disclosed. The track drive system can be configured to move the body. The track drive system can have a pulley, a pulley cap, and a track. The pulley cap can be attached to a side of the pulley facing away from the body. The diameter of the pulley cap can be equal to or greater than the diameter of the pulley.

The pulley cap can have a diameter less than the outer diameter of the track when the track is on the pulley. The pulley cap can have a track interface. The track can have a pulley cap interface. The track interface can be configured to releasably engage the pulley cap interface. The pulley cap interface can have a nub extending from the inside of the track. The track interface can have a radial vane. The track can have a first retention element (e.g., inside nubs) extending from the inside surface of the track on a first lateral side of the track. The track can have a second retention element extending from the inside surface of the track on a second lateral side of the track.

A robotic vehicle system that can have a body and a track drive system configured to move the body is disclosed. The track drive system can have at least one pulley, a track, and a pulley cap. The track can have a first inner nub on at least one lateral side. The inner nub can be mated to an inner edge of the pulley cap. The inner nub can retain the track on the pulley. The body can retain the outside edge of the track on the pulley. The track can have a second inner nub on a second lateral side.

The system can have a track guide or retention structure on the body. The track guide structure can be mated to the outside edge of the second inner nub on the second lateral side. The track guide or retention structure can include vanes on the inside of the pulley. For example, a second wheel cap can be on the chassis-side of the flipper or mobility device pulley, for example, to help keep the track guided.

The track can have a pocket along the inside surface of the track. The pulley can have one or more grooves, nubs or lateral rails extending radially outwardly from the pulley. The nubs or rails of the pulleys can interface with the pockets (e.g., depressions), for example, enabling the pulley to drive the track.

A robotic vehicle system that can have one or more torque-limited safety coupling for unfixing and rotating the mobility assistance devices or flippers with the chassis is disclosed. The robotic vehicle system can have a chassis, a mobility

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assistance component configured to propel the robotic vehicle system; and a release coupling. The release coupling can attach the chassis to the mobility assistance component. The mobility assistance component can be contractable with respect to the chassis when the release coupling is activated.

The release coupling can be configured to be activated by at least about a 30 Nm torque or at least about a 100 Nm torque applied to the mobility assistance device. The mobility assistance component can be rotatably contractable and rotatably expandable with respect to the chassis when the release coupling is activated.

The system can have a motor and a track on the mobility assistance component. The motor can be configured to drive the track around the mobility assistance component.

A method for using a robotic vehicle system comprising a chassis, a mobility assistance component, and a release coupling attaching the chassis to the mobility assistance component, is disclosed. The method can include activating the release coupling, and contracting the mobility assistance component toward the chassis after activating the release coupling. Activating the release coupling can include applying at least about a 30 Nm torque or at least about a 100 Nm torque to the mobility assistance device.

The contracting of the mobility assistance component can include rotating the mobility assistance component with respect to the chassis. The method can include expanding the mobility assistance component away from the chassis. Expanding the mobility assistance component can include rotating the mobility assistance component with respect to the chassis. The method can include driving a track on the mobility assistance device.

Yet another method is disclosed of using a robotic vehicle system. The method can include delivering a force through a robotic vehicle system powertrain in the robotic vehicle system. The delivering of the force can include generating a force, delivering the force through a first shaft or axle to a first receiver, and delivering the force from the first receiver to a second receiver. The force can be generated with a force generation component (e.g., a motor, engine) in the robotic vehicle system. The first shaft or axle can interface with the first receiver, such as an inner wheel hub. The modulus of elasticity of the first shaft can be no more than about 1000% more and no less than about 90% less than the modulus of elasticity of the first receiver. The modulus of elasticity of the first receiver can be no more than about 1000% more and no less than about 90% less than the modulus of elasticity of the second receiver.

The first receiver can have a radially inner hub of a pulley. The method can include driving a track with the pulley. The force generation component can include an electric motor.

The method can include delivering the force from the second receiver to a third receiver. The modulus of elasticity of the second receiver is no more than about 1000% more and no less than about 90% less than the modulus of elasticity of the third receiver.

For example, the first receiver can be a harder (e.g., relative to the outer wheel and track) inner wheel of a pulley. The second receiver can be a medium-hardness (e.g., relative to the axle, inner wheel, and track) outer wheel of the pulley. The third receiver can be a (e.g., relative to the wheel and axle) softer track.

The third receiver can have a radially outer wheel of a pulley. The method can include further comprising driving a track with the pulley. The third receiver can have a track on a radial outer surface of a pulley.

The first receiver can be concentric about the first shaft. The second receiver can be concentric about the first receiver.

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The surface area of contact between the first receiver and the second receiver can be greater than the surface area of contact between the shaft and the first receiver.

A system for delivering a force through a powertrain is disclosed. The system can include a power generator (e.g., motor, engine), a shaft configured to deliver power from the power generator, a first receiver attached to the shaft, and a second receiver attached to the first receiver. The modulus of elasticity of the shaft can be greater than the modulus of elasticity of the first receiver. The modulus of elasticity of the first receiver can be greater than the modulus of elasticity of the second receiver.

The system can have a third receiver attached to the second receiver. The modulus of elasticity of the second receiver can be greater than the modulus of elasticity of the third receiver.

A robotic system that can have a dimensionally small footprint (i.e., area when viewed from above) in a contracted configuration and a dimensionally larger footprint in an expanded configuration during mobility of the system is disclosed. The system can be collapsed or contracted for carrying or storage, and expanded for auto-mobility of the robotic system. The robotic system can contract and expand during auto-mobility.

The robotic vehicle system can have a body, a first mobility assistance device attached to the body, and a second mobility assistance device attached to the body. The first mobility assistance device can have a first configuration of a ready position (e.g. expanded away from the body or lengthened), and a second configuration of a stored position (e.g., contracted toward the body or shortened). The second mobility assistance device can have a first configuration of a ready position (e.g., expanded away from the body or lengthened), and a second configuration of a stored position (e.g., contracted toward the body or shortened). The mobility assistance devices can be flippers, rockets, or other locomotion devices. The mobility assistance devices can be moved into the ready position for motion, and can be moved into the stored position when not in the ready position.

The robotic vehicle system can have a body a first mobility assistance device attached to the body, and a second mobility assistance device attached to the body. The first mobility assistance device can have a first configuration extended from the body and a second configuration contracted toward the body. The second mobility assistance device can have a first configuration extended away from the body and a second configuration contracted toward the body. The system can have an extended length when the first and second mobility assistance devices are in the first configurations. The system can have a contracted length when the first and second mobility assistance devices are in the second configurations.

The robotic vehicle system can have a third mobility assistance device attached to the body. The third mobility assistance device can have a first configuration, extended from the body and a second configuration contracted toward the body. The robotic vehicle system can have a fourth mobility assistance device attached to the body. The fourth mobility assistance device can have a first configuration extended from the body and a second configuration contracted toward the body. The extended length can be when the first, second, third and fourth mobility assistance devices are in the first configurations. The contracted length can be when the first, second, third, and fourth mobility assistance devices are in the second configurations.

The extended or expanded length can be equal to or greater than about 50% of the contracted length, or equal to or greater than about 60% of the contracted length.

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A method for using a robotic vehicle system having a body, a first mobility assistance device attached to the body, and a second mobility assistance device attached to the body is disclosed. The method can include configuring the robotic vehicle system in a contracted configuration having a contracted length. The method can include expanding the first mobility assistance device from a contracted configuration to an expanded configuration. The method can include expanding the second mobility assistance device from a contracted configuration to an expanded configuration. The robotic vehicle system can be in an expanded configuration having an expanded length following the expanding of the first, and second mobility assistance devices, and wherein the expanded configuration is greater than about 50% of the contracted length.

The robotic vehicle system can have a third mobility assistance device attached to the body, and a fourth mobility assistance device attached to the body. The method can include expanding the third mobility assistance device from a contracted configuration to an expanded configuration. The method can include expanding the fourth mobility assistance device from a contracted configuration to an expanded configuration. The robotic vehicle system can be in an expanded configuration having an expanded length following the expanding of the first, second, third and fourth mobility assistance devices.

A robotic vehicle system having a body and a first mobility assistance device is disclosed. The body can have a body longitudinal axis. The first mobility assistance device can have a first mobility assistance device longitudinal axis. The first mobility assistance device longitudinal axis can intersect the body longitudinal axis. The robotic vehicle system can have a second mobility assistance device having a second mobility assistance device longitudinal axis. The second mobility assistance device longitudinal axis can intersect the body longitudinal axis.

A robotic vehicle system having a body and a pair of main tracks or mobility devices is disclosed. The main tracks can be angled (i.e., non-parallel) with respect to each other. The robotic vehicle system can have a drive system for driving the pair of main tracks. The main tracks can be toe-in or toe-out with respect to each other. The toe-in or toe-out angle can be from greater than about 0 degrees to about 90 degrees, for example about 10 degrees. The robotic system can have a first mobility assistance device attached to the body, and a second mobility assistance device attached to the body. The angle of the main tracks with respect to each other can be adjusted during use. The tracks can be toe-in for enhanced straight line stability and/or toe-out for enhanced turning sensitivity.

A robotic system is disclosed that can have a body, a mobility assistance device, a drivetrain, and a release mechanism within the assembly of the mobility assistance device and the drivetrain. The mobility assistance device can be connected to the drivetrain. The drivetrain can actuate the mobility assistance device with respect to the body. The release mechanism can be configured to allow movement of the mobility assistance device without moving at least one element of the drivetrain. The drivetrain can include a motor, shaft and gearing to transmit power from the motor to drive a track on the mobility assistance device. The release mechanism can have a safety release coupling. The release mechanism can allow the mobility assistance device to move relative to the body. The release mechanism can actuate the mobility assistance device from a ready (e.g., expanded) to a stowed or stored (e.g., contracted) position without moving all or part of the drivetrain.

A method for using a robot having a chassis and a drivetrain is disclosed. The method can include activating a release within a drivetrain connected to a mobility assistance device. Activating the release can include moving a mobility assistance device from a first position relative to the chassis to second position relative to the chassis. The first position can be a ready position from which the robot can be operated. The second position can be a stowed position from which the robot can be more easily stored than the ready position and/or still operated. Activating the release can include releasing a safety release coupling or disengaging a clutch between the mobility assistance device and the drivetrain.

Releasing the safety release coupling can include popping the coupling, for example by delivering an impact or impulse to the coupling (e.g., by dropping or throwing the robot to deliver the impulse through the mobility assistance devices and to the safety release coupling. Releasing the safety release coupling can include levering to release the coupling, activating a motor (e.g., a servo motor) a solenoid, or combinations thereof. The release of the safety release coupling can be actuated by a control, such as a button, switch, toggle, or combinations thereof.

The method can include moving the mobility assistance device from a first position to a third position, a second position to a third position, or combinations thereof.

BRIEF DESCRIPTION OF THE FIGURES

FIGS. 1a and 1b illustrate variations of the robotic system with the flippers in an extended configuration.

FIG. 2 illustrates the robotic system of FIG. 1 with the flippers in a retracted configuration.

FIG. 3 illustrates a variation of the robotic system.

FIGS. 4a and 4b are left and right side views, respectively, of a variation of the robotic system with the flippers in an extended configuration.

FIGS. 5a and 5b are top and bottom views, respectively, of a variation of the robotic system with the flippers in an extended configuration.

FIGS. 6a through 6h are top views of a variation of the robotic system with the flippers in extended and retracted configurations, respectively.

FIGS. 7a and 7b are side views of a variation of the robotic system with the flippers in retracted and extended configurations, respectively.

FIG. 8 is a front perspective view of a variation of the robotic system.

FIGS. 9a and 9b are left and right side views, respectively of a variation of the robotic system.

FIGS. 10a and 10b are top and bottom views, respectively, of a variation of the robotic system.

FIG. 11 is a schematic representation of a variation of the robotic system.

FIG. 12a is a side view of a variation of a chassis with exposed compartments.

FIGS. 12b and 13 are rear side and front side perspective views, respectively, of a variation of a partially assembled robotic system.

FIG. 14 illustrates a variation of the chassis frame.

FIGS. 15 through 20 are exploded views of variations of a partial assembly of the robotic system.

FIGS. 21 through 30 illustrate a variation of a method for assembling portions of the robotic system.

FIG. 31 is a close-up view of a variation of the gears.

FIG. 32 illustrates a variation of a portion of the robotic system including a first side plate.

FIG. 33 illustrates a variation of a portion of the robotic system including a second side plate.

FIG. 34 is a close-up view of a variation of the battery compartment.

FIGS. 35a through 35c illustrate a variation of using a door on the battery compartment.

FIG. 36 is a schematic representation of a variation of a control module of the robotic system.

FIG. 37 is a schematic representation of a variation of a power module of the robotic system.

FIG. 38 is a front view of a variation of a remote user control module of the robotic system.

FIGS. 39 and 42 are rear perspective views, FIG. 42 is also a partial see-through view, of a variation of the remote user control module of the robotic system with the rear panel in open and closed configurations, respectively.

FIGS. 40 and 41 are front and front perspective views, respectively, of a variation of the remote user control module of the robotic system.

FIGS. 43a and 43b are close-up views of the top front and bottom rear, respectively, of a variation of the remote user control module.

FIG. 44 illustrates a variation of the user control module.

FIG. 45 is a schematic of a variation of the software stack architecture for the user control module.

FIGS. 46 and 47 are top and bottom views, respectively, of variations of a payload control module.

FIG. 48 illustrates a variation of a method for attaching the payload control module to the remainder of the robotic system.

FIGS. 49 through 51 are front perspective, rear perspective, and side views, respectively, of integrated audio and video payload modules.

FIG. 52a illustrates a variation of the robotic system.

FIGS. 52b, 52c and 52d are close-up views of portions of FIG. 52a.

FIG. 53 is a close-up front perspective view of a variation of a partially assembled robotic system.

FIG. 54a is a sectional view of a variation of a pulley end cap.

FIG. 54b is a partially exploded view of a variation of a flipper.

FIG. 55 illustrates a variation of a camera payload.

FIG. 56 is a schematic representation of a variation of a drive module of the robotic system.

FIG. 57 is a schematic representation of a variation of a mobility assistance module of the robotic system.

FIG. 58 is a schematic representation of a variation of an audio payload module of the robotic system.

FIG. 59 is a schematic representation of a variation of a video payload module of the robotic system.

FIGS. 60 through 65 illustrate that the robotic system 10 can have one or more cooling devices. The cooling devices may thermally regulate the robotic system 10.

FIG. 66 is a top see-through view of a variation of a robotic system.

FIG. 67 is a side view of a variation of the robotic system shown without flipper assemblies for illustrative purposes.

FIGS. 68 through 70 are exploded views of variations of the flipper assemblies.

FIGS. 71 through 74 are perspective views of further arrangements of the mobility assistance devices of a variation of the robotic system.

FIGS. 1a and 1b illustrate a mobile robotic system 10 that can be used for remotely transporting a payload. The robotic system 10 can be configured to traverse terrain types including flats, stairs, rubble, water barriers, and to push open and pass through doors. The robotic system can be in an expanded configuration to extend the wheelbase and/or track base (i.e., the length from the distal terminal end of the longitudinally outermost wheel or track on a first longitudinal end of the system to a distal terminal end of the longitudinally outermost opposite wheel or track on a second longitudinal end of the system).

The robotic system 10 can have a chassis frame 101. The chassis frame 101 can have plates mounted to the chassis frame 101. The chassis frame 101 and plates can form a dust-proof, and/or water-proof body 20 or chassis 100. For example, the plates can form the entire outside surface, be sealed with gaskets and/or caulking and/or sealant, and have no ports or holes, or have holes or ports covered by dust-proof and/or waterproof filters. The chassis 100 or body 20 and the chassis frame 101 can be identical, for example if the system 10 has no side plates or other additional body or chassis components on the chassis frame 101.

The body 20 can be water and/or dust permeable. The body 20 can have vents or holes, for example for cooling, sampling the environment (e.g., video, audio, chemical sensors, and/or samplers), tool access, or combinations thereof.

The body 20 can contain one or more removable or permanently affixed payloads, such as cameras, video displays, microphones, speakers, transceivers (including receivers and/or transmitters), chemical sensors and samplers, weapons, or combinations thereof.

The body 20 can be attached to one or more mobility devices 200. The mobility devices can be a track system, and/or be a set of one or more wheels, skis, skates, propellers, wings, sails, blades, balloons, floats, paddles, oars, flippers, turbines, propellers, corkscrews, winches, pressure tanks, rockets, a hover system or combinations thereof. FIG. 1a illustrates that the body can have one, two or more mobility devices 200 located on each lateral side of the body 20. FIG. 1b illustrates that the body 20 can have one or more mobility devices 200 located laterally within the body. The mobility devices 200 can be laterally central to the body 20.

The track system can have mobility device tracks 210 mounted onto mobility device track drive pulleys and a mobility device track guide. The mobility device track can be driven, as shown by arrows 30, by the mobility device track drive pulleys along the mobility device track guide. The mobility device track device pulleys can be actively powered by one or more motors, and optionally transmissions, in one direction or controllably reversible directions, and/or passively free-spinning, and/or attached to a full-time engaged, or engageable and releasable clutch to prevent rotation in a first direction while allowing rotation in a second direction (e.g., to prevent backing up or sliding downhill, for example when carrying a payload or towing a load). The mobility device track 210 can engage with the ground surface and propel the system 10.

One or both of the mobility devices 200 can have a mobility device dummy track. For example, the mobility device dummy track can be located where some or all of the mobility device track 210 would have been located. The mobility device dummy track can be a single, plastic molding that has an appearance similar to the mobility device track 210, or a part of the mobility device track 210 that is not driven. The mobility device dummy track can be not in contact with the

ground surface. For example, the mobility device dummy track can not extend to the bottom of the mobility device 200. The mobility device dummy track can drag or slide along the ground surface when the system 10 is moved. The mobility device dummy track can be a chain cover that covers a drive chain for driving one or both flippers.

The body 20 can be attached to one, two, three, four or more mobility assistance devices 300, such as flippers 301, wheels, skis, skates, propellers, wings, sails, blades, balloons, floats, paddles, oars, flippers, turbines, propellers, corkscrews, winches, pressure tanks, rockets, a hover system, a floating device such as a foam or gas-inflated (e.g., air or carbon dioxide) bladder, or combinations thereof. The mobility assistance devices 300 can have a mobility assistance device track that can driven, as shown by arrows 40, and guided by one or more mobility assistance device pulleys, and guided by a mobility assistance device track guide.

The flipper tracks can all be driven in the same direction. Any one, two, three, or four flipper tracks can be driven in a first direction while the remaining flipper tracks can be driven in a second direction, opposite to the first direction, locked in place (e.g., via a clutch or brake), allowed to slide freely along the mobility assistance device pulleys and mobility assistance track guide, or combinations thereof.

For example, the flipper tracks on a first lateral side of the body 20 can be driven in a first direction while the flipper tracks on the laterally opposite side of the body 20 can be driven in the second direction, opposite to the first direction, locked in place (e.g., via a clutch or brake), allowed to slide freely along the mobility assistance device pulleys and mobility assistance track guide, or combinations thereof (e.g., to turn the body). The flipper tracks on a first lateral side of the body 20 can be driven in opposite directions to each other while the flipper tracks on the laterally opposite side of the body 20 can be driven in directions similar to or opposite to the direction driven by either of the tracks on the first lateral side of the body 20, locked in place (e.g., via a clutch or brake), allowed to slide freely along the mobility assistance device pulleys and mobility assistance track guide, or combinations thereof (e.g., to turn the body).

The flipper tracks on a first longitudinal side of the body 20 (e.g., the front or back) can be driven in a first direction while the flipper tracks on the longitudinally opposite side of the body 20 can be driven in the second direction, opposite to the first direction, locked in place (e.g., via a clutch or brake), allowed to slide freely along the mobility assistance device pulleys and mobility assistance track guide, or combinations thereof (e.g., to churn or rub the ground surface with the tracks). The flipper tracks on a first longitudinal side of the body 20 can be driven in opposite directions to each other (e.g., to churn or rub the ground surface with the tracks) while the flipper tracks on the second, longitudinally opposite side of the body 20 can be driven in directions similar to or opposite to the direction driven by either of the tracks on the first longitudinal side of the body 20, be locked in place (e.g., via a clutch or brake), allowed to slide freely along the mobility assistance device pulleys and mobility assistance track guide, or combinations thereof.

The flipper tracks on diametrically opposite sides of the body 20 can be driven in a first direction while the flipper tracks on the diametrically opposite side of the body 20 can be driven in the second direction, opposite to the first direction, locked in place (e.g., via a clutch or brake), allowed to slide freely along the mobility assistance device pulleys and mobility assistance track guide, or combinations thereof (e.g., to intentionally churn or rub the ground surface with the tracks). The flipper tracks on diametrically opposite sides of the body

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20 can be driven in opposite directions to each other (e.g., to rotate the body **20**) while the remaining flipper tracks (e.g., those on the other diametrically opposite corners of the body **20**) can be driven in directions similar to or opposite to the direction driven by either of the tracks on the first longitudinal side of the body **20**, be locked in place (e.g., via a clutch or brake), allowed to slide freely along the mobility assistance device pulleys and mobility assistance track guide, or combinations thereof.

Four flippers **301** can be located at the laterally and longitudinally opposite corners of the body or main track, as shown. Two flippers **301** can be at a single longitudinal end (e.g., front or back) of the body **20** with no flippers at the opposite longitudinal end. Two flippers **301** can be on a single lateral side of the body **20**, with no flippers **301** on the opposite lateral side. Two flippers **301** can be placed at diametrically opposite corners of the body **20** with the remaining corners having no flippers **301**.

The driven mobility assistance device tracks can be driven in the same and/or opposite directions to the driven mobility device tracks. For example, all the driven mobility assistance device tracks can be driven in the same direction as the driven mobility device tracks. The mobility assistance device tracks on a first lateral side can be driven in the same first direction as the driven mobility device track on the first lateral side when the mobility device track and the mobility assistance device tracks on the second, opposite lateral side is driven in a second direction, opposite the first direction, for example to rotate the system **10** (e.g., without translating the system away from the current location of the system **10**).

When the flippers **301** are in an extended configuration, as shown in FIGS. **1a** and **1b**, the longitudinally distal ends of the flippers **301** can extend past the longitudinally distal ends of the chassis, body **20** and/or the mobility device **200**.

FIG. **2** illustrates that the mobility assistance devices can be longitudinally contracted or retracted toward the longitudinal center of the body **20**. For example, the flippers **301** can individually, in lateral, longitudinal, or diametrically opposite pairs, and/or concurrently rotate, as shown by arrows **50**, toward the longitudinal center of the body **20**. The flippers **301** can be positioned to not exceed the top or bottom height of the body **20**. For example, the flippers **301** can be within the side-view footprint of the body **20**.

The robotic system can be in a retracted or contracted configuration to minimize the effective wheelbase and/or track base, for example for storage, carrying, maneuvering smaller clearances while driving the system **10**, throwing the robotic system **10** (e.g., through a window into an unsecure building or room), or combinations thereof.

FIG. **3** illustrates that the mobility devices can be skids or skis **202**. The skis **202** can be low friction, smooth panels. The skis **202** can define a ski plane. The skis **202** can be coated with a low friction material, such as wax, polymer (e.g., PTFE, such as Teflon® from EI DuPont de Nemours & Co., Wilmington, Del.), oil, another lubricant, or combinations thereof. The skis can be high friction, roughened panels. The skis **202** can be textured, having knurls, spikes, brads, vanes, fins, or combinations thereof extending outwardly from the plane of the ski **202**.

The skis **202** can have ski tips **204** that can extend from one or both of the longitudinal ends of each ski **202**. The ski tips **204** can extend longitudinally past the longitudinal terminus of the body **20**. The ski tips **204** can be in plane with the skis **202** or curve, bend, or angle out of plane with the ski **202**. For example, the ski tips **204** can curve toward the center of the body **20**, as shown in FIG. **3**. The ski tips **204** can curve away from the center of the body **20**.

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FIGS. **4a** and **4b** illustrate that the robotic system can have a first, second, and third robotic system antennas **60a**, **60b**, and **60c**. The antennas **60a**, **60b**, and **60c** can be fixed to or removable from plugs on the top surface of the body **20**. The antennas can be attached to electronic hardware inside of the body **20**, but exit the body **20** through ports through panels on the top of the body **20**. The antennas can be straight, as shown, curved, triangular, smart antenna arrays, springs, or combinations thereof. The antennas **60a**, **60b**, and **60c** can extend from about 0 cm (0 in.) to about 1 m (3 ft.), more narrowly from about 2 cm (0.8 in.) to about 60 cm (20 in.), for example about 20 cm (8 in.) up from the body **20**. The antennas **60a**, **60b** and **60c** can be rigid, flexible, or combinations thereof.

The antennas **60a**, **60b**, and **60c** can receive and send signals for data and/or power to and from a remote operator control module, a central operations command, a second robotic system, or combinations thereof. One or more of the antennas **60a**, **60b**, and **60c** can alternatively or additionally be a cord extending to the destination and/or source of the signal and/or power.

The antennas **60** can have a removable interface (e.g., BNC, TNC, SMA), for example, for quick assembly and disassembly to the body **20**. The antennas **60** can be located inside the body **20**. For example, the body **20** and/or side plates can be made of a material (e.g., plastic) that does not shield internal antennas **60** from incoming RF signals and block outgoing signals. The antennas **60** can be mounted on a flexible mount. The antennas **60** can be attached to the body **20** by or articulatable or folding mounts. The flippers **301** can extend from the front and back of the body **20**. The bottoms of the flippers **301** can be substantially coplanar with the other flippers **301** and/or with the bottom surface of the body **20**.

The body **20** can have one, two, or more mobility device tracks **210**. The mobility device tracks **210** can be powered or driven to deliver force against the ground surface in contact with the bottom or top of the mobility device track **210**.

FIGS. **5a** and **110b** illustrate that the mobility device tracks **210** can have mobility device track axes **209**. The track axes **209** can be parallel with each other, or at positive or negative mobility track angles **208** with respect to each other. For example, the mobility device tracks **210** can have adjustable toe-in (i.e., a positive mobility track angle **208**) or toe-out (i.e., a negative mobility track angle). The toe-in can add stability to the steering and straight line stability at low and high speeds. The mobility track angle can be from about -10° to about $+10^\circ$, for example about 0° . For toe-in configurations, the mobility track angle **208** can be from about 0.5° to about 10° , more narrowly from about 10° to about 5° , for example about 3° . The mobility track angle **208** can be adjustable, for example by adjusting an alignment bolt on one or both mobility devices **200** and/or by controlling servo motors or solenoids attached to one or both mobility devices **200**.

One, two, three, four or more of the flippers **301** can have mobility assistance device tracks **310**. The mobility device tracks **310** can encompass the outer perimeter of the flippers along a vertical plane parallel with the plane of the flipper **301**. The flippers **301** (e.g., the non-tracked flippers) can have no track, skids, skis, tires, or combinations thereof.

The inside nubs **216** and/or outside nubs **211** can be separated, individual nubs, as shown, and/or one or more rails extending along part or all of the length of the track. For example, the rail can have nublets extending toward (e.g., medially) or away from (e.g., laterally) the center of the width of the track. The inside nubs **216** (or **316**) or nublets can hold the track **210** (or **310**) on the pulleys **220** (or **320**) and/or track guides and/or rollers, and/or extend into and engage with a track interface, such as the radially extending vanes **345**, of

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the pulley caps **240** and **340**. The inside nubs **216** (or **316**) or nublets can mate, engage and disengage the radially extending vanes as the pulley caps **240** and **340** rotate attached to and synchronized with the pulleys **220** (or **320**) and the track **210** (or **310**) moves along the pulleys **220** (or **320**). Radially extending vanes can be on the pulley **220** (or **320**) to engage the inside nubs **216** (or **316**).

The inside nubs **216** and/or outside nubs **211** can be spaced apart from the adjacent, respective, nubs **216** and/or **211** by from about 1 cm (0.4 in.) to about 5 cm (2 in.). For example, the outside nubs **211** can be spaced apart by about 42 mm (1.6 in.). Also for example, the inside nubs **216** can be spaced apart by about 14 mm (0.55 in.). The inside nubs **216** and/or outside nubs **211** can extend laterally across the part or all of the width of the mobility device track **210**. For example, the outside nubs **211** can be located in longitudinally equal pairs with one nub of each pair located on the lateral inside of the mobility device track and the other nub of the pair located on the lateral outside of the mobility device track **210**. The outside nubs **211** can increase the traction or friction between the tracks **210** and the ground surface adjacent to the tracks **210**.

One, two, three, four or more of the flippers **310** can have mobility assistance device tracks **310**. The mobility device tracks **310** can encompass the outer perimeter of the flippers along a vertical plane parallel with the plane of the flipper **301**. The flippers **310** (e.g., the non-tracked flippers) can have no track, skids, skis, tires, or combinations thereof.

The mobility assistance device **300** can have a mobility assistance device pulley or flipper pulley **320**. The flipper pulley **320** can receive power from a power source, such as a motor, and deliver it to the mobility assistance device track **310**. The outer lateral side of the flipper pulley **320** can be attached to and covered by a mobility assistance device pulley cap **340**. The mobility assistance device pulley cap **340** can have one, two or more angular (e.g., about 360°) vanes and/or one or more (e.g., from about 3 to about 30, for example about 12) radial mobility assistance device vanes **342b** and recessions.

The flipper **301** can have a mobility assistance track guide **330**. The flipper **301** can have a mobility assistance track guide arm **331**. The mobility assistance track guide arm **331** can be vertically inside of or contained by the mobility assistance track guide **330**. The mobility assistance track guide arm **331** can be attached to and/or integral with and/or interference fit within the mobility assistance track guide **330**.

The mobility assistance track guide **330** and the mobility assistance track guide arm **331** can have angular and radial mobility assistance track guide vanes **350a** and **350b**, respectively, and recessions. The angular mobility assistance track guide vanes **350a** can extend from a first terminal side of the mobility assistance track guide **330** or mobility assistance track guide arm **331**, to a second terminal side of the mobility assistance track guide **330** or mobility assistance track guide arm **331**.

The flipper **301** can have roller wheel caps **336** (and **337**), for example attached to the lateral inside and outside of a roller wheel (shown infra). The roller wheel caps **337** can have a diameter larger than the roller wheel, for example interference fitting against, retaining and guiding the mobility assistance device track **310** on the flipper **301**.

FIG. 17 illustrates that the tracks **210** and **310** can have track large outer diameters **402a** and track large inner diameters **402b**, for example along the pulleys **220** and **320**. The track large outer diameters **402a** can be from about 5 cm to about 35 cm, for example, about 15 cm.

The track large inner diameters **402b** can be from about 4 cm to about 34 cm, for example, about 14 cm.

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The mobility assistance device tracks **310** can have track small outer diameters **404a** and track small inner diameters **404b**, for example along the roller wheels **335**. The track small outer diameters **404a** can be from about 2 cm to about 20 cm, for example, about 4 cm.

The track small inner diameters **404b** can be from about 2 cm to about 19 cm, for example, about 3 cm.

The track guide caps **337** and **336** can have inner and outer track guide cap diameters **406a** and **406b**, respectively. The track guide cap diameters **406a** and **406b** can be from about 2.1 cm to about 19.1 cm, for example, about 3.5 cm.

FIG. 18 illustrates that the pulleys **220** and **320** can have pulley diameters **410**. The pulley diameters **410** can be from about 4 cm to about 34 cm, for example, about 14 cm.

The pulley end caps, mobility device pulley caps **240** or mobility assistance device pulley caps **340** can have pulley cap diameters **412**. The pulley cap diameters **412** can be from about 4.1 cm to about 34.1 cm, for example, about 14.1 cm.

FIG. 14 illustrates that the side plates **150** can have sideplate heights **414**. The sideplate heights **414** can be from about 4.1 cm to about 34.1 cm, for example, about 14.1 cm.

When the tracks **210** and/or **310** are in a cool or unexpanded state, the track large outer diameters **402a** can be larger than the pulley cap diameters **412** and sideplate heights **414**, for example to maintain contact between the track **210** and/or **310** and the ground surface. When the tracks **210** and/or **310** are in a warm or expanded state, the track large inner diameters **402b** can be smaller than the pulley cap diameters **412** and sideplate heights **414**, for example to laterally restrain the tracks **210** and/or **310** (e.g., by interference fitting) on the respective track guides and pulleys.

When the mobility assistance device tracks **310** are in a cool or thermally unexpanded state, the track small outer diameters **404a** can be larger than the inner and outer track guide cap diameters **406a** and **406b**, for example to maintain contact between the mobility assistance device tracks **310** and the ground surface. When the mobility assistance device tracks **310** are in a warm or thermally expanded state, the track small inner diameters **404b** can be less than the inner and outer track guide cap diameters **406a** and **406b**, for example to laterally restrain the mobility assistance device tracks **310** (e.g., by interference fitting) on the respective track guides and pulleys.

The flipper **301** can have a modulus of elasticity at 73° F. of from about 280,000 to about 420,000. The flippers **301** can be rigid enough to provide support for the mobility assistance tracks **310** between the axes of the roller wheel and the pulley. The flipper **301** can transmit torque to effectively rotate the mobility assistance device. The flipper **301** can flex on impact, or while being twisted/torqued in ways other than about the axis of rotation of the device.

The pulley wheels **220**, **221**, and **320** can have a modulus of elasticity at 73° F. of from about 8,000 to about 12,000. The tracks **210** and **310** can have a modulus of elasticity at 73° F. of from about 2,400 to about 5,600. The antennas can have a modulus of elasticity at 73° F. of from about 16,000 to about 24,000.

The body **20** can have one or more side doors **70** on one or both sides, and/or front and/or back, and/or top and/or bottom. For example, the side door **70** can be between the top of the mobility device track **210** and the bottom of the mobility device track **210**. The side doors **70** can access the first, second, third or other compartments. Each side door **70** can access a single compartment or a single side door can access two, three or more compartments.

The body **20** can have a side door latch **72**. A first part of the side door latch **72** can be fixed to the side adjacent to the seam

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between the side door **70** and the side plate adjacent to the side door **72**. A second part of the side door latch **72** can be fixed to the side door **70**. The side door latch **72** can be unlatched opened or latched closed, fixing the door closed. The side door **72** can be locked and unlocked. For example, the side door **72** can be locked during operation of the system **10** and unlocked for cleaning, replacing payloads, maintenance or combinations thereof.

One (as shown) or both lateral sides, and/or one or both longitudinal ends, and/or the top and/or the bottom can have doors similar to the side door **70** with or without latches.

The mobility assistance device track **310** can have mobility assistance device track outside nubs **311** and/or mobility assistance device track inside nubs **316**. The outside nubs **311** can be on the outside surface of the mobility assistance device tracks **310**. The inside nubs **316** can be on the inside surface of the mobility assistance device tracks **310**. The inside nubs **316** and/or outside nubs **311** can be studs, spikes, brads, cleats, anchors, rails, or combinations thereof. The inside nubs **316** and/or outside nubs **311** can be integral with and/or removably attached to the mobility assistance device tracks **310**.

The inside nubs **316** and/or outside nubs **311** can be spaced apart from the adjacent, respective, nubs **316** and/or **311** by from about 1 cm (0.4 in.) to about 5 cm (2 in.). For example, the inside nubs **316** can be about 14 mm (0.55 in.) apart, and the outside nubs **311** can be about 42 mm (1.7 in.) apart. The inside arils **316** and/or outside nubs **311** can extend laterally across the part or all of the width of the mobility assistance device track **310**. For example, the outside nubs can be located in longitudinally equal pairs with one nub of each pair located on the lateral inside of the mobility assistance device track **310** and the other nub of the pair located on the lateral outside of the mobility assistance device track **310**. The outside nubs **311** can increase the traction or friction between the mobility assistance device tracks **310** and the ground surface adjacent to the tracks **310**.

FIGS. **5a** and **5b** illustrate that the body **20** can have a first, second, and third compartment for holding removable payloads. The first, second and third compartments can be accessed through first, second and third interfaces, respectively. The first, second and third interfaces can be covered with first, second and third interface covers **74**, **76** and **176**, respectively. The interface covers **74**, **76** and **176** can be attached to the body **20** with cover attachment devices **80**, such as screws, bolts, fast-release (e.g., cotter) pins, snaps, latches, or combinations thereof.

One, two or three of the interface covers **74**, **76** and **176** can have ventilation and/or sound openings **78**, such as vents, pores, filters, holes grids, a screen-covered, fabric-covered and/or mesh-covered and/or grate-covered opening, or combinations thereof. The openings **78** can be waterproof and/or dust-proof. The robotic system **10** can have a speaker and/or microphone can be located inside of the openings **78**. A ventilation fan, manifold or conduit can be located inside of the openings **78**.

The body **20** can have an open or covered payload bay **175**. One or more payloads can be loaded into and permanently fixed or removably attached or detachable from to the payload bay **175**.

The body **20** can have one or more top body panels **80a** on the top side of the body **20**, one or more bottom body panels **82b** on the bottom side of the body **20**, one or more payload bay body panels **82c**, side front and rear body panels, and combinations thereof. The body panels can be reinforced and plated. For example, the body panels can be made from iron, steel, aluminum, titanium, plastic, ceramic, laminated glass,

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polycarbonate thermoplastic, crystal, carbon fiber layers, depleted uranium, buckypaper, aluminum foam, or composites or other combinations thereof.

The body panels can be from about 2.5 mm (0.098 in.) to about 14 mm (0.55 in.) thick, for example with external and internal ribs to provide support. The ribs also act as vanes to dissipate heat. The ribbed design can create a high-strength, lightweight chassis that has extra surface area, compared with a rib-less body, for example for dissipating heat.

The body panels can be thermally conductive and sink heat away from the motors and other heat-generating electric components. The body panels can have radiative heat transfer vanes **86**, for example, to dissipate heat from the electric components into the environment outside of the body **20**.

The mobility assistance devices **300** can have mobility assistance device pulley caps **340** attached to the lateral outside of the mobility assistance device pulleys that can drive the mobility assistance device tracks **310**. The mobility assistance device pulley caps **340** can have a rounded lateral outer surface, for example forming a mobility assistance device pulley end cap radius of curvature **84**. The mobility assistance device pulley end cap radius of curvature **84** can be from about 10 cm (4 in.) to about 21 cm (8.3 in.), for example about 162 mm (6.38 in.). When the robotic system **10** is positioned or falls onto the side of the robotic system **10**, the curvature of the mobility assistance device pulley end caps **340** can induce the robotic system to passively or actively (i.e., by activating the mobility assistance device **300**) fall onto the top or bottom of the robotic system **10**, for example enabling any of the tracks **210** and/or **310** to contact the ground surface and propel the robotic system **10**.

FIGS. **54a** and **54b** illustrate that the mobility assistance device pulley end caps **340** can include ribs **3401** for structural support, and a steel backing plate **3402** which can be from about 1 mm to about 2 mm thick. One or more dowel holes **3404** in the steel, backing plate **3402** can permit one or more dowel pins **3403** to enter into or pass through the steel backing plate **3402**. The dowel pins **3404** can be integral with and extend from, or press into the flipper arm **330**. The dowel pins **3403** can be pressed into the pulley cap **340** to prevent rotation and to preserve rotational orientation of the flipper arm **330** and the wheel cap. The dowel pins **3403** can be cylindrical, or have an oval, square, triangular, pentagonal or hexagonal cross-section.

The chassis **100** can have a handle **178** extending from one or both of the longitudinal ends of the chassis **100**. The handle **178** can be configured to form an ergonomic gap between the handle **178** and the chassis **100**. The handle **178** can support the hanging weight of the robotic system **10** and a fill complement of payloads and other components loaded onto the chassis **100**. For example, the handle **178** and chassis **100** can support from about 2 kg (5 lbs) to about 45 kg (100 lbs), more narrowly from about 5.4 kg (12 lbs.) to about 27 kg (60 lbs.), yet more narrowly from about 16 kg (35 lbs.) to about 23 kg (50 lbs.).

FIG. **6a** illustrates that the body **20** can have a body longitudinal axis **354**. The mobility devices **200** can have mobility device longitudinal axes **356**. The mobility assistance devices **300** (e.g., flippers **301**) can have mobility assistance device longitudinal axes **358**.

The mobility assistance device longitudinal axes **358** can intersect the body longitudinal axis at one or more mobility assistance device-body angles **360**. The mobility assistance device longitudinal axes **358** can intersect the mobility device longitudinal axes **356** at one or more mobility assistance device-mobility device angles **362**.

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The mobility assistance device-body angles **360** and/or the mobility assistance device-mobility device angles **362** can be zero (e.g., parallel axes) or non-zero. The mobility assistance device-mobility device angles **362** can be from about 0° to about 180°, more narrowly from about 5° to about 15°, for example about 10°. The mobility assistance device-body angles **360** can be from about 0° to about 180°, more narrowly from about 5° to about 15°, for example about 10°.

The flippers **301** can be vertically raised and lowered with respect to the body **20** and mobility devices **200**, for example, to prevent the flippers from contacting the ground surface and to lift the mobility devices **200** so the drive forces from the mobility devices **200** do not conflict with the direction of the drive forces applied to the ground surface by the flippers **301**. The flippers **301** and mobility devices **200** can contact and apply a driving force to the ground surface concurrently, even when the mobility assistance device-mobility device angles **362** are not about 0°.

The robotic system **10** can have one, two, three, four or more steering rods **352** that can be attached to the flippers **301**. The steering rods **352** can be translatably powered and controlled by servo motors, solenoids, or combinations thereof. The steering rods **352** can extend laterally from the body **20**. The steering rods **352** can translate laterally inward and outward, shown by arrows **364**. The translation of the steering rods **352** can change the mobility assistance device-body angle **360** and the mobility assistance device-mobility device angles **362**.

Each steering rod **352** can be synchronized or controlled independently. The mobility assistance device-body angles **360** can be adjusted to rotate or steer the robotic system **10**.

The drive axles **149** can extend laterally from the body **20**, for example, about perpendicular to the body longitudinal axis **354**. The drive axles **149** can be laterally extendable and retractable to position the flippers **301** away from the mobility devices **200** at the location of the drive axles **149**. For example, the drive axles **149** can be positioned to position the flippers **301** flush with and adjacent to the mobility devices **200** at the location of the drive axles **149** with no substantial gap between the flippers **301** and the mobility devices **200**.

The mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** of the flippers **301** at a first longitudinal end of the robotic system **10** can be about the negative of mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** of the respective laterally corresponding flippers **301** at a second longitudinal end of the robotic system **10**.

FIG. **6b** illustrates that the mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** of the flippers **301** at a first longitudinal end of the robotic system **10** can be about equal to the mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** of the flippers **301** at a second longitudinal end of the robotic system **10**.

The flippers **301** can all be parallel. The steering rods **364** for all the flippers **301** can be synchronized and/or fixed to each other.

FIG. **6c** illustrates that the left lateral front flipper **301** can be parallel with the right lateral front flipper **301**, and the left lateral rear flipper **301** can be parallel with the right lateral rear flipper **301**, for example to actively steer the robotic system **10**, but the front flippers **301** can be optionally fixed to be parallel or not parallel with the rear flippers **301**.

FIG. **6d** illustrates that the flippers **301** can be retracted or contracted, as shown by arrows. Some or all of the flippers

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301 can have non-zero mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** in a retracted or contracted configuration.

FIG. **6e** illustrates that the flippers **301** at a first longitudinal end of the robotic system can have mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** of about 0° in a retracted or contracted configuration. The flippers **301** at the second longitudinal end of the robotic system **10** can have non-zero mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** in a retracted or contracted configuration, for example not interference fitting against the flippers **301** at the first longitudinal end and compacting into a laterally symmetric footprint (when viewed from the top or bottom).

FIG. **6f** illustrates that flippers **301** at first diametrically opposite corners of the robotic system **10** can have mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** of about 0° in a retracted or contracted configuration. The flippers **301** at second diametrically opposite corners of the robotic system can have non-zero mobility assistance device-mobility body angles **360** and/or the mobility assistance device-mobility device angles **362** in a retracted or contracted configuration, for example not interference fitting against the flippers **301** at the first longitudinal end and compacting into a diagonally symmetric footprint (when viewed from the top or bottom).

FIG. **6g** illustrates that flippers **301** of the robotic system **10** can be laterally offset from one another. Any or all of the flipper **301** can extend up to approximately the length of the chassis **20** for the robotic system

FIG. **6h** illustrates that in a compacted, contracted or folded configuration, any or all of the flippers **301** can be equal length to the chassis **20**. Any or all of the flippers **301** can have proximal and distal (i.e., front and back) longitudinal termini at equal longitudinal positions to the proximal and distal (i.e., front and back) longitudinal termini of the chassis **20**. The robotic system **10** can be carried in a backpack. The chassis length can be about 10 in. The flipper length can be from about 8 in. to about 10 in. FIG. **7a** illustrates that the mobility assistance devices **301** on a lateral side of the robotic system **10** can have complimentary shapes in a contracted and/or retracted configuration. The shapes of the mobility, assistance devices **301** can retract (e.g., rotated inward).

For example, each flipper **301** can have more than one roller wheel **335** to form each flipper **301** to not interference fit against the other flippers **301** on the same lateral side of the robotic system **10** when the flippers **301** are in a retracted or contracted configuration, in an extended configuration or moving between different configurations.

FIG. **7b** illustrates that when the flipper **301** can be in an extended configuration. The flipper **301** at a first longitudinal end on a lateral side of the robotic system can contact the ground surface **372** along the substantially entire length of the flipper **301**. The flipper **301** at a second longitudinal end on the same lateral side of the robotic system can contact the ground surface along about the entire length of the flipper **301**, or upon less than about the entire length of the flipper **301**, for example along about half of the length of the flipper **301**. The flipper **301** can form a flipper rise **364**. The flipper rise **364** can be the gap under a leading terminal end of the flipper **301**. As the robotic system is moving in the direction of the flipper rise **364**, obstacles can encounter the flipper initially in the flipper rise **364**, under the flipper **301**. The flipper can then be pressed upward as the flipper **301** contacts and is forced onto the obstacle.

FIGS. 8 through 10b illustrate that the robotic system 10 can have no mobility assistance devices. The mobility devices 200 can be the lateral termini of the robotic system 10.

The mobility devices 200 can have mobility device pulley end caps 240. Each mobility device pulley end cap 240 can have a mobility device pulley end cap radius of curvature 284. The mobility device pulley end cap radius of curvature 284 can be from about 10 cm (4 in.) to about 21 cm (8.3 in.), for example about 162 mm (6.38 in.). When the robotic system 10 is positioned or falls onto the side of the robotic system 10, the curvature of the mobility device pulley end caps 240 can induce the robotic system 10 to passively or actively (i.e., by activating the mobility device 200) roll onto the top or bottom of the robotic system 10, for example enabling any of the tracks 210 to contact the ground surface and propel the robotic system 10.

As shown in FIGS. 11 through 14, the robotic system 10 can include a chassis 100 which can house a power supply 110, a control module 120, and a drive module 130 connected to at least one mobility device 200. As shown in FIGS. 19 through 20, the control module 120 can include a remote operator control unit 127. As shown in FIG. 21, the power module can regulate and control the power to the control module 120. As shown in FIGS. 11 and 22, the drive module 130 can include at least one gearbox 132, at least one motor 134, and at least one motor controller 136. As shown in FIGS. 2 through 25 respectively, audio and video payloads may be attached to the robotic system 10. As also shown in FIGS. 11 and 23, the chassis 100 may house a mobility assistance module 140 connected to a mobility assistance device 300. As shown in FIGS. 17 and 18, the mobility assistance device 300 can be at least one flipper. The flipper can resemble a pinball machine flipper. The flipper can have a movable track 310. At least one flipper can be actuated, two flippers can be actuated, or any number of flippers may be automatically or manually actuated. As shown in FIGS. 26 through 29 the flippers may be actuated in a number of different positions depending on the application.

FIGS. 12a through 16 illustrate that the chassis 100 can support all of the components of the robotic system 10.

FIG. 12a illustrates that the chassis 100 can have component-receiving chassis rails 374. The component-receiving chassis rails 374 can extend inwardly from the walls of the chassis 100. The chassis 100 can be made with an extrusion process. Any or all of the compartments 103, 104 and 105 can have one or more rails 374.

The components can have component rails and/or grooves that can be configured to be slidably received by the rails 374. The chassis rails 374 can be separate elements from the chassis 100 and/or can be extruded profiles integral with the chassis 100. The components can have snaps, clips, detents, other lockable configurations or features, or combinations thereof that can interface with the chassis rails 374. The components can be slid into the chassis 100 along one or more chassis rails 374, and locked, fixing the component against the chassis rail 374 and/or chassis wall. The components can be unlocked, detached from the chassis, and, for example, removed from the chassis 100. The components can be removed from the chassis 100 for maintenance, modification, specializing the robotic system, controlling weight, weight distribution, power usage, and combinations thereof.

The chassis rails 374 can each have one or more rail legs 376 and rail arms 378. The rail leg 376 can extend perpendicularly from the chassis wall or compartment wall. The rail arm 378 can extend perpendicularly from the rail leg 376. For example, the rail arm 378 can extend from the end of the rail leg 376 that is farthest from the wall from which the rail leg

376 extends. The chassis rails 374 can be curved. For example, the chassis rails 374 can have an arc shape.

The chassis rails 374 can be placed in pairs, such as a first chassis rail 374a and a second chassis rail 374b paired with the first chassis rail 374a. The first chassis rail 374a can be positioned in the opposite orientation as the corresponding second chassis rail 374b. A component can be configured to be slidably and/or lockably received by a first chassis rail 374a and the corresponding second chassis rail 374b.

The chassis 100 can protect components of the robotic system 10 which may include electronic components, motors, power supplies, payload components, mobility assistance devices, and any other components of the robotic system 10. As shown in FIGS. 12b and 13, the chassis 100 can include a chassis frame 101.

FIGS. 14 through 16 illustrate that at least one side plate 150 can be configured to close the chassis frame 101. The side plate 150 may partially close the chassis frame 101.

FIGS. 12b and 13 illustrate that the chassis frame 101 can be divided into a first and second compartment 103, 104. The chassis frame 101 can have a third compartment. The second compartment 104 can include the third compartment 105. However, the chassis frame 101 can include one, two, three, four, five, six or more compartments, arranged in any suitable configuration for housing any number of modules and/or robotic system components.

For example, the actuator modules can be located close to the mobility devices to minimize material in the robot's design. The power source compartment can be located so that the power module can connect via a sliding-fit connector when the power source is placed in its compartment. Also, for the current configuration the power source (e.g., which can be relatively heavy) can be located close to the axis of rotation of the flippers that will be rotated to "self-right" the robotic system 10 when the robotic system 10 is upside down. This configuration can have a center of gravity close to the axis of rotation, which can help stability of the robotic system 10 for self-righting.

The chassis frame 101 can house about eight modules, for example, a control board, power board, front I/O board, audio board, two drive actuators, a flipper actuator, a safety coupling gear system, or combinations thereof. Electrical cabling can connect the modules. Gearing, axles, shafts and other mechanical components can connect the modules. The chassis frame 101 can have a desiccant, for example for removing moisture. The chassis frame 101 can have a lubricant.

The body plates can be made from machined aluminum alloys, extruded, or die-cast. The body plates can have ribs, for example, to increase strength and provide increased surface area. The ribs can be more prevalent around the high stress and/or high-heat areas of the body and plates, such as at connection points for fasteners, front, rear and top, bottom impact points, bearing journals, axes of rotation and mounting points for payloads. The materials can be plated and/or hardened with anodizing, forging or heat-treating processes.

The first compartment 103 of the chassis frame 101 can house and/or include at least one drive module 130. The first compartment 103 of the chassis frame 101 can house and/or include a mobility assistance module 140. A second compartment 104 of the chassis frame 101 can house a power supply 110 and a control module 120. The second compartment 104 can house and/or include a third compartment 105 for housing a control module 120 separately from the power supply 110.

FIGS. 12b and 13 illustrate that the chassis frame 101 can include at least one payload interface 171, 172, 173. The interfaces 171, 172, 173 can be holes in the body 20. The

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interface **172** is shown open. A speaker grill **78** and microphone **181** can be attached to or be part of an audio module payload mounted to the chassis. The audio module payload can be covered instead with a simple plate, such as shown by interface **173**. The interface **173** can also be expanded with an external actuator, device, sensor, or combinations thereof. The interfaces can be adapted to attach and/or connect payload modules. The payload modules can be attached to the chassis frame **101** and/or payload connections **174** adapted to connect payload modules **170** a control module **120**, power supply **110**, or any other suitable robotic system component.

The chassis **100** can have payload bay **175** that can hold payloads. The bay **175** can have one or more mounting points for attaching to payloads, and/or can carry payloads or gear loose (e.g., like a fiat pickup truck bed with walls). The interface **170** can be removed and some variation added, so in that sense it can be a payload.

FIG. **14** illustrates that additional payload modules **1750** may be attached to the chassis frame **101** of the robotic system **10**, and can use a rail or a nub or other mechanical feature **1752** molded or attached to the chassis frame **101**, and the mechanical feature **1752** can be mated with a corresponding mechanical feature **1751** in the payload module **1.750**, for example a trough mated to a rail. For payloads designed for a specific payload bay **175** on the robotic system **10**, the mechanical features **1751**, **1752** may be keyed, for example, to prevent attachment to a payload module **1750** in an incompatible position, which may damage electronics if a wrong connector is used, or may alter the balance of the robotic system **10**.

The chassis **100** can be made of metal, for example aluminum, titanium, copper, steel, iron, brass, sheet metal, or combinations thereof. The chassis **100** may be made of a non-metal material, such as carbon fiber, polycarbonate, concrete, metal foam, wood, a polymer, or combinations thereof. The chassis **100** can be manufactured via a machining process, extruded, molded, cast, stamped, carved, welded or combinations thereof.

Plastics described herein can be Delrin or other suitable polymers. The plastics can be machined, molded, extruded, shaped or combinations thereof.

FIG. **15** illustrates that a chassis **1001** can include a solid watertight shell and a substructure for load-bearing. The chassis **1001** can be made from formed sheet metal. The substructure can be made entirely from sheet metal. The substructure sides **1002**, **1003** can be formed of sheetmetal. The substructure top can be folded sheetmetal or can be completely or partially riveted or welded in place. The shell can have first and second shell sides **1004** and **1005**, respectively. The shell sides **1004**, **1005** can be attached to the substructure sides **1002**, **1003**. The top cover can include an extra lip that can be inserted, into a groove in side panels **1004**, **1005** for sealing. The side panels **1004** and **1005** can be made from plastic. The chassis **1001** may include a heatsink cover **1009** on the back of the chassis to seal around the motor heatsink **1258**. The heatsink cover **1009** can be made from plastic. The heatsink cover **1009** can seal the edges of the cover on three edges per side.

FIG. **16** illustrates that a welded chassis core **1010** can have removable panels. The chassis core **1010** can be partially or fully made from seam welded sheet metal. The chassis core **1010** can be water-tight. Removable side panels **1012**, **1004**, **1005** or top panels **1011** may enable access to the center of the robotic system **10**. The cover may be welded on. The cover may not be removable in the field and/or during assembly. A face seal can be used to seal any side panels **1012**, **1004**, **1005**

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and top panels **1011**, including plastic to sheet metal interfaces, however it may not be as reliable of a seal as the groove seal.

FIG. **17** illustrates that a core chassis **1021** protected by a sliding cover **1022** can house the robotic system **10**. The core chassis **1021** can be watertight or non-watertight. All electronics can be mounted in the core. Wires and cables can be routed inside the core precent to, concurrent with, or subsequent to mounting the electronics in the core. A side plate can be attached to a rear drive system motor and/or at least one flipper system motor. A sliding cover **1022** can then be slid over the core chassis **1021**. Each side plate **1004**, **1005** can be attached with motors and fans affixed to the side plates **1004**, **1005**. Wires can be routed to keep a groove seal between the edges of the chassis cover **1022** and the side plates **1004**, **1005**.

FIG. **18** illustrates that a core chassis **1031** may have a shell. The shell can be plastic. The shell can include a bottom. The bottom can be plastic. The shell may or may not be attached to sides **1034**, **1035** and one or more top cover(s) or panel(s) **1032**. The top panels **1032** can be sheet metal or plastic. The sides **1034** and **1035** can be plastic. The sides **1034**, **1035** can be bonded along the keel line, for example to form a butt joint seal. A gasket or an o-ring can be bonded along the keel line, for example to form a seal. The plastic can be clamped, screwed or adhered together to hold the seal tight. A single top panel can allow access to almost the fill top of the system. The sides **1034**, **1035** can be sealed to the plastic using a face seal, which may include a wipe seal or an o-ring seal. The rear heatsink seal can be plastic to plastic. The core **1031** can support internal component mounts and rigidity. The top panel **1032** may be sealed. The payload connections can be watertight. The core **1031** may include a heatsink cover **1009** on the back of the chassis **1001** to seal around a motor heatsink **1258**. The heatsink cover **1009** can have a cover seal at the edges of the cover **1009**. For example the heatsink cover **1009** can have a cover seal on 3 edges per side.

FIG. **19** illustrates that the chassis can include a core **1041**. The chassis **1001** can be made entirely from plastic. The core can be plastic. The chassis **1001** can include structural panels **1042**, **1043**. The structural panels **1042** and **1043** can be made from sheet metal. The core **1041** can include stiffeners **1042**, **1043**, for example, on the side panels **1004**, **1005**. The stiffeners **1043** can be made from sheet metal. The motors can be mounted to the structural panels **1042**, **1043**. The motors can be mounted or not mounted to the sides **1004**, **1005**. The sides **1004**, **1005**, can be bolted to the core **1041**. The sides can be made from sheet metal. The motors and other components requiring a rigid support structure can be mounted to the. The electronics, for example, the power board, can run wiring outside the main plastic/sheetmetal enclosure. The cable routing service can also be simpler. Side caps can cover the components. Seals can be plastic-to-plastic, o-rings, face seals, gaskets, or combinations thereof.

FIG. **20** illustrates that a chassis **1051** can be include a cover plate or sheet metal skid plate **1052**, a plastic skid-plate, or a cover or skid plate. The chassis **1051** can be made from injection molded plastic, or machined, cast, extruded, or combinations thereof. The chassis **1051** can be attached to an accessibility panel on the side, front, rear, top or bottom of the chassis **1051** in addition to or instead of the removable skid plate **1052**. The accessibility panel can be made from sheet metal and/or plastic. The cover plate or skid plate **1052** can be sealed with a skid plate gasket to the inside of the chassis **1051**. The skid plate gasket can prevent or minimize sand, water, liquids, and gasses from entering the chassis **1051**.

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FIG. 21 illustrates that the right side can be attached, as shown by arrow S10, such as by fastening, to the core 1001. The use of right and left sides is provided for clarity, however the right and left sides may be reversed in the assembly process. Each side may have more than one piece.

FIG. 22 illustrates that a controller board 1202 can be attached to the core 1001. Attaching the controller board 1202 to the core 1001, can include attaching the controller board 1202 to a controller heatsink, and attaching the controller heatsink to the core 1001. The core 1001 can have a solid attachment wall. The solid attachment wall can be attached to or behind the controller board 1202. The solid attachment wall can be made from sheet metal. The solid attachment wall can be a heatsink or heatpipe for the controller 1202.

FIG. 23 illustrates that second, third or more controller boards or daughter boards, for example a power controller board 1202, an audio/visual controller board 1203, a payload interface board 1204, or combinations thereof, can be attached to the sheet metal core 1001.

FIG. 21 illustrates that the front shaft can be passed, as shown by arrow S20, through the right side and through the core 1001. The sideplates can include bushings (e.g., Iglide® plastic bushings from Iigus®, inc. of East Providence, RI). The bushings can be about 155 mm in diameter. The bushings can be pressed into the side.

FIG. 24 illustrates that the power supply 110 can be inserted into the lateral side of the chassis, and the payload control module 128 can be attached to the top of the partially assembled robotic system, as shown by respective arrows.

FIG. 25 illustrates that the gear assembly can be slid, as shown by arrows S22, on the rear shaft after it has been placed in the side plate 150, for example, concurrent with the front shaft passing through the right side and the core 1001.

FIGS. 26 and 27 illustrate that the front shaft assembly, which can include a shaft or axle 149 and gear, such as a ring gear 139, can be slid, as shown by arrows S24, into the side plate 150, for example, concurrent with the front shaft passing through the right side and the core 1001. Sliding the front shaft assembly into the side plate can include attaching the motors to the side plate.

FIG. 28 illustrates that sliding the front shaft assembly into the side plate 150 can include attaching, as shown by arrow S27, the gears to the motors. Attaching gears to the motors can include inserting a motor shaft 2774 through a locating adapter plate 2770. The locating adapter plate 2770 can be made from steel. The motor shaft 2774 can be pressed into an adapter hub 2771 inside the gear 2772. The hub 2771 can include a D-shaped hub at the top of the shaft 2774. The hub 2771 can include a slip fit at the bottom of the shaft 2774. The gear 2772 can be attached to the motor shaft 2774 using an M3 set screw, a heat stake, or combinations thereof.

Sliding the front shaft assembly into the side plate 150 can include applying lubricant to the gears. Applying lubrication to the gears can include applying at least one lubricant, such as grease or graphite, to the gearing system.

FIG. 29 illustrates that sliding the front shaft assembly into the side plate 150 can include covering, as shown by arrow 529, the motor and shaft gears with a gear cover or gear housing 3441. Covering the motor and shaft gears with a gear cover can include placing a gear cover over the interlocking motor gears attached to the motors and the shaft gears attached to the front and rear shafts. The gear cover can protect the motor and shaft gears from debris. The gear cover can seal in lubricants previously applied to the motor and shaft gears.

The cover can be slid, as shown by arrow S30 (as shown in FIG. 21), over the core 1001. Sliding the cover over the core

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1001, can include sliding the cover over the core support. Sliding the cover over the core 1001, can include sealing the cover to the core 1001, for example to make the chassis 100 watertight. The cover can be made from polymer, such as plastic.

The left side can be attached, as shown by arrow S40, to the core 1001. Attaching the left side to the core 1001 can include attaching the side plate to the core support and/or the cover. Attaching the left side to the core 1001 can include sealing the left side to the core 1001, for example to make the chassis 100 watertight. Attaching the left side to the core 1001 can include attaching, as shown by arrow S42, a motor to the side plate.

The gear assembly can be slid, as shown by arrow S50, over the front shaft. Sliding the gear assembly over the front shaft can include securing the gear assembly to the front shaft. Sliding the gear assembly over the front shaft can be concurrent with sliding gears over the rear shafts of the robotic system 10. Sliding the gear assembly over the front shaft can be concurrent with attaching gears to the rear shafts. Sliding the gear assembly over the front shaft can include applying bearings, spacers, snap rings, and/or washers to the gear assembly and/or the front shaft. Sliding the gear assembly over the front shaft can include applying, as shown by arrow S58, lubrication to the gears, and covering, as shown by arrow S59, the gears with a gear cover.

Methods of assembling any or all of the system described here can be performed in the sequence shown in the figures and/or described in the text herein or any permutation thereof.

FIG. 30 illustrates that the side plate 150 can close the chassis frame 101, for example to protect the internal components, and provide additional structural support. The side plate 150 can include a sealing device 151, which can seal the space between the chassis frame 101 and the side plate 150.

FIG. 29 illustrates that the side plate can include a mated gear housing 3441. The mated gear housing 3441 can protect and align the gears. During assembly and maintenance, the gears can be placed inside the gear housing 3441, which can be installed from the outside, and can be held in place by gear cover. The gear housing 3441 can contain lubricants for gears. The gear housing 3441 can be externally serviceable, for example additional lubricant can be applied to the gears, while keeping the inside of the robotic system 10 clean and free of lubricants and possible gear chips or other contaminants. The gear housing 3441 can protect the gears from external contaminants such as sand, water, dust, or combinations thereof. The gears can be heat staked to hubs.

FIG. 31 illustrates that positions of one or more of the gears 131, 139 can be tracked and/or measured by at least one potentiometer 3442. Two potentiometers 3442 can be used. For example, the two potentiometers 3442 can be rotated 90 to 180 degrees with respect to each other. Each potentiometer can output a potentiometer signal, for example a first potentiometer can output a first potentiometer signal and a second potentiometer can output a second potentiometer signal. A processor can receive the combined first and second potentiometer signals. The process can use the first and second potentiometer signals to calculate the relative rotation of at least two gears with respect to each other. The potentiometers can have equal to or less than about 360 degrees of usable motion, or more narrowly from about 300 degrees to about degrees of usable motion. One or more potentiometers can measure finer measurements, feedback, redundancy, faster calculations, or combinations thereof.

The sealing device 151 can be a gasket seal made of an elastomer, such as silicon rubber, a wax paper gasket, foam, caulk, glue, any other suitable gasket or sealing device, or combinations thereof. The seal can be watertight and/or air-

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tight, but may provide any suitable level of sealing, to prevent pebbles, sand, dirt, silt or any other material from entering the chassis frame **101**, but may alternatively be made of any suitable material. The side plate **150** can be fastened to the chassis frame **101** using at least one fastener, to prevent particles from getting inside the chassis **100**. The side plate fastener can be made of, for example, at least one machine screw, rivet, latch, interlocking snap-together component, glue, any other suitable fastener, or combinations thereof. The fastener fastening the side plate **150** to the chassis frame **101** can be sealed using a sealing device, for example a standard silicon rubber o-ring washer for a machine screw, another sealing device or sealant, or combinations thereof.

As shown in FIG. **30**, the side plate **150** can include an interface **152** to allow a drive module **130** to transfer mechanical energy out of the chassis **100** to a mobility device **200**. The interface **152** can enable a mobility assistance module **140** to transfer mechanical energy out of the chassis **100** to a mobility assistance device **300**.

As shown in FIG. **30**, the mechanical energy can be transferred from the drive module **130** to the mobility device **200** using a rotatable axle sleeve **153**, but may alternatively be an axle. The rotatable axle sleeve **153** can be a rotating sleeve surrounding a seal around an axle **149**, allowing the seal to rotate while maintaining a watertight seal around an axle **149**. The seal can occlude more than water, including other liquids, gases, dirt, debris, and any other external or internal contaminants. The inside of the rotatable axle sleeve **153** can include a pair of seals **155**, **156**, for example single lipped o-ring seals, at least one static seal, or combinations thereof. The seals **155**, **156**, can be made of neoprene, any suitable elastomer or sealing material, or combinations thereof. The space **157** in between the seals **155**, **156** can be filled with a lubricant, such as grease, graphite, oil, any other suitable lubricant, or combinations thereof. The watertight seal can retain a lubricant and provide a long service life. The rotatable axle sleeve can be adapted to rotate with a ring gear **139** using at least one pin **154**, attached in any suitable fashion, or combinations thereof. The rotatable axle sleeve **153** can include a bearing **158**, for example to allow an axle **149** inside the rotatable axle sleeve **153** to rotate freely.

As shown in FIG. **30**, the rotatable axle sleeve **153** can be held in position in the side plate with a bearing **160**. The rotatable axle sleeve **153** can be sealed using a sealing device **161**. The sealing device **161** can be a watertight double lipped O-ring seal, and a lubricant can be applied to the sealing device to provide a long service life. The seal can occlude more than water, including other liquids, gases, dirt, debris, and any other external or internal contaminants. The sealing device **161** can be made of neoprene. The sealing device **161** can be placed on the inside of a flanged divider **162** in the interface **152** of the side plate **150**. The bearing **160** can be placed on the outside of the flanged divider **162** of the interface **152** of the side plate **150**. The bearing **160** can be fastened in place using a fastener **159**, for example a snap ring **159**, but any suitable fastener may be used. The bearings **158**, **160**, can be a sealed ball bearing, for example a rugged sealed stainless steel, ball bearing, but may alternatively be a shielded bearing, a ceramic bearing, a chrome plated steel ball bearing, a thrust bearing, a sleeve bearing, a radial bearing, or any other suitable bearing.

As shown in FIGS. **30** and **32** the side plate **150** can include an axle **169**, for example a motorized axle or a dead axle, attached to a manually actuated mount **167**. The manually actuated mount **167** can enable the rotation of the axle **169** and be held in a fixed position with a pin **168**. The pin **168** may be removed and the rotation of the axle **169** may be adjusted

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manually and locked into at least one specific position with a pin **168**, but any suitable number of adjustable positions may be possible. The axle **169** may be actuated by a mobility assistance module **140** or any other suitable driving mechanism. The axles **149**, **169** can be keyed on the outer end, for example the key **163** can be hex shaped, square, triangular, splined, other suitable shapes, or combinations thereof. The axles **149**, **169** may be splined, keyed, or combinations thereof. The outer ends of the axles **149**, **169**, outside the keying, can be threaded or adapted to fasten a mobility device **200** and/or a mobility assistance device **300** to the axle **149**, **169**.

The power supply **110** can provide power to the robotic system **10**. The power supply **110** can be the BB2590 standard battery manufactured by Bren-tronics, the BB4590 standard battery, nuclear batteries, any other suitable battery, fuel cell, solar panel, power supply, or combinations thereof. The power supply **110** can be removable to allow repair, recharging, refueling, and/or replacement. As shown in FIGS. **12b**, **13** and **33**, the power supply **110** can be inserted into a second compartment **104** of the chassis frame **101**, and connected to the control module **120** using a power supply connector **111**, for example via a standard BB2590 connector designed to interface with a single BB2590 standard battery, but may alternatively interface with a BB4590 standard battery, a fuel cell, a lithium battery, a rechargeable battery, a nuclear battery, an alkaline battery pack, solar panels, power cables, multiple BB2590 batteries, or any other suitable power source or combination of power sources. The connector **111** can form a watertight connection with the power supply **110**, but may also occlude more than water, including other liquids, gases, dirt, debris, and any other external or internal contaminants. The power supply **110** can be a BB2590 battery and can be inserted into the chassis **100** through a hole in the chassis side plate **150**. The power supply **110** can be secured in a second compartment **104** of the chassis frame **101** with a fastener, a door **115** closed with a draw latch **116**, a clamp, thumbscrew, or other suitable latch mechanism or fastener, or combinations thereof. A toolless and quick mechanism to enable the quick change of a power supply **110** can be used.

FIG. **34** illustrates that a toolless mechanism can change the power supply **110**. An eject lever **1161** can eject the power supply **110** from a battery compartment **2000**. The eject lever **1161** can manipulate a pushbar **1163** along a guided path **1164**. The pushbar **1163** can eject the power supply **110**, such as the battery, from the battery compartment **2000**. A pullbar **1162** may be pulled, as shown by arrow. The pullbar **1162** can be a flat aluminum sheetmetal ribbon or panel and can have right angle turns at distal and proximal ends. When the pullbar **1162** is pulled, the pullbar **1162** can in turn pull the power supply **110**, such as the battery, out of the battery compartment **2000**.

FIGS. **35a**, **35b**, and **35c** illustrate that a toolless mechanism can change the power supply **110**. The battery compartment can be covered by the toolless mechanism. The mechanism can include a drawbridge door **1151**.

FIG. **35a** illustrates that the drawbridge door **1151** can be open and fully extended.

FIG. **35b** illustrates that the drawbridge door **1151** can be open and partially extended and partially folded.

FIG. **35c** illustrates that the drawbridge door **1151** can be closed. The drawbridge door **1151** can include an internal door extension **1152** and an external door extension **1153**. The fastener **1167** can attach the external door extension **1153** to the internal door extension **1152**. The fastener **1167** can hold the power supply **110**, such as the battery, in place. The

fastener **1167** can be a half-turn or quarter-turn D-ring, knob, hook, a keyed lock, or combinations thereof.

As shown in FIGS. **11** and **36**, the control module **120** can be adapted to manage power output from the power supply **110**, control the drive module **130**, and/or control a mobility assistance module **140**, payload modules **170**, or any other modules that may be attached to the robotic system **10**. As shown in FIG. **18**, the control module **120** can include at least one microprocessor **121**, and a power module **122**. In a further variation the control module **120** can include an operator control module **126**, and may include at least one payload control module **128**.

The microprocessor **121** can manage and control input and output from the different modules within the control module. The microprocessor **121** can be a (re)programmable microprocessor, an FPGA, an ASIC, a circuit, any other suitable control logic, or combinations thereof. The microprocessor **121** can be programmed with software logic to enable the robotic system **10** to run independent of any human operator, run a pre-configured program (e.g. secure the area, map the area, travel from point A to point B, collaborate with other robots), or any other suitable program. The microprocessor can be connected to a tilt sensor or tilt switch to detect if the robotic system **10** is inverted, and if the robotic system **10** is inverted, the microprocessor **121** may then execute a control program to flip the robotic system **10** to a non-inverted position and allow the robotic system **10** to resume normal operations.

The power module **122** can monitor the output of the power supply **110**, and reset or regulate the power supply **110** when the output is either above or below a desired threshold. The power supply **110** can be a BB2590 battery. The BB2590 battery can be a multi-purpose battery, and can have protection logic and/or circuitry that turns off the battery when a current output specification is exceeded. The control module **120** can enable a power supply **110**, for example a BB2590 battery, to continue providing normal currents after the high current protection has been triggered, enabling such a power supply to be used for applications using high currents (even momentarily), such as driving an electric motor, or when a vehicle or device using an electric motor becomes jammed, dropped or otherwise stressed. The BB2590 battery can be reset by dropping the current draw to below approximately 2 milliamps, and the BB2590 will again output current.

FIG. **37** illustrates that the power module **122** can include a connection to the power supply **110**, a delay circuit **92**, a voltage monitor **93**, an enable switch **94**, and a current throughput switch **95**. The power module **122** can have one cell protection circuit **91**, and a charging circuit **96**.

The power supply **110** can have two batteries. Each battery can be a group of four cells of the standard BB2590 battery. The cell protection circuit **91** can prevent the group of cells with the highest voltage from charging the group of cells with the lowest voltage, which could trigger the protection circuitry of the BB2590 battery. The cell protection circuit **91** can be at least one diode, for example one diode per group of four cells, but may be any suitable circuit.

A delay circuit **92** functions to reduce and or turn off the current draw for a period of time, which enables a BB2590 to reset. The delay circuit **92** can be controlled by a voltage monitor **93**, which functions to monitor the voltage output from the power supply **110** and trigger a delay in the delay circuit **92** (for example, while a capacitor in the delay circuit **92** charges) to reset the power supply **110** when the power supply output drops below (or alternatively spikes above) a threshold. The delay circuit **92** can discharge (the charge from the capacitor) quickly and charge slowly, and can provide

most of the delay while a capacitor charges. The power supply **110** can reset sometime after a capacitor in the delay circuit **92** has started recharging. The voltage monitor **93** can include a voltage divider, which can control an N-channel mosfet controlling a P-channel mosfet.

FIG. **11** illustrates that the P-channel mosfet of the voltage monitor **93** can output Vcontrol, which can power the control module **120** and may provide the voltage Vcontrol for the charging circuit **96**. When the delay block is lowering the voltage across the voltage divider, the N-channel mosfet in the voltage monitor **93** turns off the P-channel mosfet, cutting off power to Vcontrol which can send a power off signal to an enable switch **94**, cut off power to the control module **120**, and may cut off power to the charging circuit **96**, or combinations thereof. For a hard reset, the power to Vcontrol and Vout can both be reset and/or cycled simultaneously.

The enable switch **94** can be an N-channel mosfet, a P-channel mosfet, any other suitable switch, or combinations thereof. The enable switch **94** can be connected to an N-channel mosfet of a current throughput switch **95**. An N-channel mosfet of the current throughput switch **95** can control at least one P-channel mosfet, for example two P-channel mosfets as shown in FIG. **21**. Two P-channel mosfets, one per cell of a BB2590 battery, can be more power efficient than a single P-Channel mosfet, however, any suitable configuration of N-channel and P-channel mosfets, or any other switching mechanism and/or circuit may be used. The current throughput switch **95** can include a diode, or two diodes, for example one diode connected to each P-channel mosfet. The diodes in the current throughput switch can be high-powered schotkey diodes rated for 80-100 Amps, but can be any suitable diode. The current throughput switch **95** can include an enable signal, Vout_enable, connected to a pin of the microprocessor **121** the control board **120**, enabling the microprocessor **121** to control the output of the N-channel and P-Channel mosfets and thus turn the voltage Vout on and off using an enable signal.

The power module **122** can include a charging circuit **96**. The charging circuit **96** can include a P-channel mosfet controlled by an N-channel mosfet. Any suitable combination of N-Channel and P-channel mosfets, or any other suitable switching device may be used. The charging circuit **96** can be controlled by an enable signal, Vcharge_enable, can be connected to a pin on the microprocessor **121** on the control board **120**. When the charging circuit **96** is enabled, the P-channel mosfet can allow current to flow through the resistor and the diode of the current throughput circuit **95**, for example, to charge any capacitors connected to Vout, such as the capacitors of a motor controller, or an air compressor. However, capacitors connected to Vout can be charged without the charging circuit **96**; the charging circuit **96** can function to limit the max current that the capacitors can draw from the power supply **110**, otherwise each time the capacitors are charged, the protection circuitry of the power supply **110** (for example a BB2590 battery) may be triggered.

The power module **122** can operate as follows. The BB2590 is either inoperable, replaced, or has exceeded an output limit, is not outputting power and requires a low current draw below 2 milliamps to be reset. The voltage Vbat_low_current is low and the delay circuit **92** turns off the enable switch **94** and can turn off Vcontrol, power to the control board **120**. The current throughput switch **95** and the charging circuit **96** can be not powered while the BB2590 battery is reset. Once the BB2590 battery has been reset, the delay circuit **92** is no longer providing a delay as the capacitor is recharging or has been recharged, and the voltage monitor provides power to the control module **120**, and disables the

enable switch **94**. The microprocessor **121** of the control module **120** then can enable the charging circuit **96** to charge any capacitors connected to Vout (e.g. motor controller applications require large electrolytic capacitors), but this may not be necessary if the application does not require capacitor charging. The microprocessor **121** of the control module **120** can disable the charging circuit **96** after an appropriate amount of charging time, and enable the current throughput switch **95**, enabling high current flow to Vout. The entire process takes approximately 0.33 seconds, and a fast reset is potentially unnoticeable to the operation of the robotic system **10**, and not substantially affect the operation of the robotic system **10** or the user experience.

The power module **122** may include a charge storage unit, which can function to maintain power to the power module **122** and/or the microprocessor **121** if the power supply **110** is not supplying power. The charge storage unit may power the entire control module **120** while the power supply **110** is not supplying power. The charge storage unit can be at least one capacitor, at least one battery, an alternative power supply, any other suitable source of power, or combinations thereof.

FIGS. **36** and **38** illustrate that the operator control module **126** can receive user input to control the robotic system **10**. The operator control module **126** can include a remote operator control unit (OCU) or remote operator control module **125**, and may include at least one payload control module **128**.

The operator control module **126** may enable the selection of a pre-configured control program (e.g. secure the area, map the area, travel from point A to point B, collaborate with other robots), which may or may not require additional user input, or any other suitable program. The operator control module may include a switch to select between multiple programs. The switch may be a keypad, a selector dial, a firmware reprogramming, a sequence of button pressings, any other suitable device or method of selecting a program, or combinations thereof.

The operator control module **126** can be connected to a remote user control module **125**, for example the operator control module **126** can be connected to at least one remote user control module **125** using at least one wireless link. The control circuitry may be distributed in any fashion across the remote user control module **125** and the operator control module **126**. For example, the control circuits (e.g., microprocessors) can be on the operator control module **126**, the robotic system **10**, a payload attached to the robotic system **10**, or combinations thereof. The processing can be split in any combination between the operator control module **126**, the robotic system **10**, a payload attached to the robotic system **10**. For example, any of the operator control module **126**, the robotic system **10**, and a payload attached to the robotic system **10** can perform all, some or none of the processing required by the operator control module **126**, the robotic system **10**, and a payload attached to the robotic system **10**.

The operator control module **125** can be adapted to receive user input using at least one user input device **124**. The user input device **124** can be a directional joystick, but may additionally or alternatively include directional pads, trackballs, buttons, microphones (e.g., receiving input control signals via voice), mobile phone keypads, computer keyboards, a computer mouse, a touchpad, any other suitable input device, or combinations thereof. The operator control module **125** can process user input with a microcontroller, for example a programmable interface controller (PIC), a simple input processing circuit, such as a button debouncing circuit, or combinations thereof. The control signals can be transmitted from the remote operator control module **125** to the operator control

module **126** on the control board **120** of the robotic system **10** using a transceiver. The transceiver can include an FM transmitter, for example transmitting at approximately 440-480 MHz, but any suitable transmitter and/or transmission carrier frequency may be used, including a digital transmission link, a wireless networking link, IEEE 1394 link, USB 1.0 2.0 3.0 link, any other suitable link, or combinations thereof. The transmitter can be connected to an antenna **123** tuned to the transmission carrier frequencies of approximately 440-480 MHz. The operator control module **126** can include a transceiver, for example having an FM receiver, and an antenna, connected to an antenna port **127** (shown in FIG. **12b**). The control data can flow from the remote operator control unit **125** to the operator control module **126**, and/or flow from the operator control module **126** to the remote operator control unit **125**.

The remote operator control module **125** can be powered by a NiMH rechargeable battery, an AC adapter, a cigarette lighter adapter, a BB2590 battery, a solar cell, any other suitable power supply, or combinations thereof. The rechargeable battery can be recharged through a power port **117**, which may charge the battery from an AC adapter, a cigarette lighter adapter, a BB2590 battery, a solar cell, any other suitable power supply, or combinations thereof.

The casing of the remote operator control module **125** can protect the components inside. The casing can be made of ABS (or another low moisture absorption polymer), aluminum, titanium, nylon, other metals or polymers, wood, carbon fiber, any other suitable material, or combinations thereof. The case can be sized such that the entire remote operator control module will fit into a pair of standard tactical cargo pants (with the antennas removed—the antennas can be quickly detachable for storage). For example, the case can be about 280 mm by about 160 mm. The remote operator control module **125** can be small enough (e.g., about 300 mm by about 150 mm) that a user may control the robotic system **10** with one hand, for example enabling a soldier or a rescue worker to hold tools, weapons, or emergency supplies in their other hand.

FIGS. **39** through **41** illustrate that an upright OCU case for an operator control module may be about 160 mm by 280 mm and 40 mm deep. The antenna **123** can transmit and receive control data, audio data, visual data, or combinations thereof.

FIGS. **39** and **42** illustrate that the operator control module **125** may have a first removable radio control unit **1251**. The first removable radio control unit **1251** may be removed and replaced with a second removable radio unit. The second removable radio unit can, for example, be identical to the first removable radio unit except for identification data, such as a serialized SIM card. The second removable radio unit can communicate on a different frequency or a different channel than the first removable radio unit. The second removable radio unit can include a different signal encryption, or a cable line unit that connects to the robotic system **10** and transfers data to and from the robotic system **10** using a copper wire or a fiber optic cable. The removable radio control unit **1251** can be removed by pulling on a wire handle. The wire handle can rotate outward from a snap tight location on the top of the operator control module **125**, a gap **1252** between the rear of the operator control module **125** and the removable radio control unit **1251** or a combination thereof.

The operator control module **125** can include a utility loop **1253**. The utility loop **1253** can be configured to hang the OCU case from a user's belt, vest, neck lanyard, or otherwise affix to a person or support structure. The operator control module **125** can include a recharging port **1254**. The recharging port **1254** can connect to a power source external to the

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operator control module **125** to charge the internal battery, or connect an additional battery to power the operator control module **125**. The recharging port **1254** can be an IP67 power connector with a dust cap.

The operator control module **125** may include a data interface **1255**. The data interface **1255** can enable the operator control module **125** to control another device and expand functionality of the operator control module **125**. The data interface **1255** may enable the operator control module **125** to act as a slave device to another system, such as a laptop computer. The data interface **1255** can include at least one wired or wireless interface, such as USB, IEEE 1394, eSata, bluetooth, WiFi, GPRS, GSM, GPS or combinations thereof. For example, the data interface **1255** can be a USB type A receptacle with a dust boot. One or more data interfaces **1255** can be housed inside the OCU case. The data interfaces can be connected to the OCU board.

The operator control module **125** can include a cooling system, which can include a fan **1257**, a motor heatsink **1258**, or some combination thereof. The fan **1257** can also be a blower or other circulation device, and can circulate air across the heatsink. For example, the blower can be an IP55 rated blower. The OCU case can include an air intake **1259** that can allow the fan to take in colder air and remove warmer air.

The operator control unit **125** can have an openable and/or removable rear panel **1256** or blower cover that can be opened and closed, as shown by arrow. The panel **1256** can cover the fan **1257**, motor heatsink **1258** and other components of the control unit **125**.

The operator control unit **125** can have an OTS COM express module **2001**. The operator control unit **125** can have one, two or more OCU power supplies, for example OCU battery packs **2002**. The operator control unit **125** can have one, two or more desiccants, such as desiccant bags **2003**. The operator control unit **125** can have a custom molded gasket **2004** between the front housing panel and the rear housing panel. The OCU **125** can have a fluid-tight or waterproof volume inside of the OCU.

FIGS. **40** and **41** illustrate that the operator control unit **125** can have a control panel **24** below the display interface **199** (e.g., a 5.7 in. touchscreen and LCD). The control panel **24** can have a payload toggle **2005** that can be configured to control the payload, for example turning the payload on and off.

The control panel **24** can have a driving joystick **2006** that can be configured to control the direction and speed of the robotic system. The control panel **24** can have a light button **2007** that can be configured to control the light or lights on the robotic system. The control panel **24** can have a menu button **2008** that can be configured to reverse to a prior screen in the operating system for the operator control unit **125**. The control panel **24** can have a payload joystick **2009** that can be configured to control the payload, for example controlling direction of the payload, such as direction or a pan-tilt camera in the payload or of a robotic arm in the payload. The control panel **24** can have a driving toggle **2010** that can be configured to control the robotic system, for example by turning the driving joystick **2006** on and off or toggling the driving joystick between the robotic system and payload or multiple robotic systems. The control panel **24** can have a microphone button **2011** that can be configured to control the microphone **2013**, for example toggling between transmitting and receiving modes for the operator control unit **125**.

The operator control unit **125** can have a front housing **2012** (e.g. injection molded polycarbonate) and a rear housing. The operator control unit **125** can have a microphone **2013** (e.g., an IP67 microphone). The operator control unit

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125 can have a rear-facing or front-facing light **2014** (e.g., a powered LED). The operator control unit **125** can have a volume toggle **2015** configured to increase or decrease the acoustic volume of the speaker **189** (e.g., an IP65 speaker) or the gain for the microphone **2013**.

FIGS. **43a** and **43b** illustrate that cameras may be added to the operator control module **125**. FIG. **43a** illustrates that an operator facing camera **1260** can be included in the operator control module **125**, and can be oriented to face the operator or user of the operator control module **125**. FIG. **43b** illustrates that a general purpose camera **1261** can be in the operator control module **125**. The general purpose camera **1261** can enable the operator of the operator control module **125** to capture images while operating a robotic system using the operator control module **125**. The operator facing camera **1260** and the general purpose camera **1261** can include a flash or other illumination device. The operator facing and general purpose cameras **1260**, **1261** can be 5 megapixel cameras.

FIG. **44** illustrates that the operator control module **125** can include input/output devices. For example, the operator control module **125** can have at least one display interface or touchscreen **12501**. The operator control module **125** can include at least one analog joystick **12502** and/or at least one analog button. The touchscreen **12501** can be used to display video feeds, or software applications. The touchscreen **12501** can display virtual buttons for controlling the robotic system **10**, robotic system payloads, communicating between other robot controllers, communicating with other communications devices (such as laptop computers, cell phones, satellite phones, space stations, websites, computer networks, or combinations thereof). The touchscreen **12501** can be an LED screen or an OLED screen.

The operator control module **125** can be powered by an ARM processor such as an ARM **9** processor or other ARM or custom designed processor.

FIG. **45** illustrates that the software stack of the operator control module **125** can include a base operating system **12511**. The base operating system **12511** can be adapted for security, optimized for communications, optimized for business specific tasks. The base operating system **12511** may include hypervisor functionality. For example, the base operating system **12511** can have multiple operating system images running on top of or inside the base operating system **12511** while the base operating system **12511** shares the hardware resources. For example the base operating system **12511** can be a hypervisor for at least one image of the Android Operating system **12512**, the Avatar Operating System **12513**, and any other suitable operating system such as Windows Mobile, iOS, Linux, Windows, MacOS VMWare, or combinations thereof. Additional applications such as an Android application and an Avatar application **12514**, **12515**, respectively, can execute on top of the Android Operating System and Avatar Operating System **12512**, **12513**, respectively. The applications **12514** and **12515** can be downloaded from an networked application store, such as the Android app store, the Chrome app store, iTunes, or combinations thereof. Such applications **12514** and **12515** can interface with data collection software, databases, image processing software, targeting or image recognition software, peer to peer communication software, collaboration software or combinations thereof. As shown in FIGS. **12b** and **13**, a payload module **170** can include an interface **175** to the control module **120**, to enable the control module **120** and/or the operator control unit **126** of the control module **120** to control the devices in the payload module **170**. As shown in FIGS. **36**, **38**, **58** and **59**, the operator control module **126** can include at least one payload control module **128** which can control and transmit

data to and/or from any payload modules **170** attached to any payload interfaces **171**, **172**, **173**. The payload control circuitry may be distributed in any fashion across the remote user control module **125**, the payload control module **128**, and the operator control module **126**.

The payload could have one of more processors, or no processors. The circuitry for an external payload could either be in that payload, or in the compartments. All of the circuitry of the payload control module **128** could be contained within the robotic system **2**. All of the circuitry of the payload control module **128** could be in the payload **170**, or the robot system **10** could include a separate microprocessor **121** and the payload **170** could include a separate microprocessor and the two processors can be configured to communicate data and control signals with each other. A separate antenna could enable a microprocessor within a payload to communicate directly with an operator control module **126** or a remote operator control module **125**. All of the processing can be handled by microprocessors on the robotic system **10**, on processors on the remote control **125**, on processors on a module/payload added to the robotic system **10**, or the processing can, be split up and handled between, any of those locations in any amount.

FIGS. **46** and **47** illustrate that a first payload control module **128** can be configured to be removed from the system **10** and replaced (e.g., swapped out) with a second payload control module. For example the second payload control module can have encryption or indentifying data that can match the encryption or identifying data in the radio or communications component of the corresponding operator control module **125**. The robotic system **10** can communicate with the operator control module **125** with encryption or identifying data, for example for use during situations or for regulatory areas where certain frequencies of communication or methods of communication are attempted to be jammed, eavesdropped on, banned by regulation, or combinations thereof.

FIG. **47** illustrates that the housing **1282** for the payload control module **128** can be made of a cast Aluminum. The housing **1282** can be a box. The housing **1282** can be a closed shape. The housing **1282** can have a cap **1283**. The cap **1283** can be made from sheet metal, aluminum, plastic, or combinations thereof. The payload module **128** can interface with a payload interface **171**, using a connector **1284**. A watertight payload seal **1285** can be between the payload module **128** and the payload interface **171**. The watertight seal **1285** can be an o-ring seal. An antenna **1286** can be used, and can be removable from the system **10**. The first antenna **1286** can be replaceable with a second antenna. A heatsink **1287** can be integrated with or separately attached to the housing **1282**. The payload control module **128** can interface to the robotic system **10** using a PCI-Express payload interface, USB, Firewire, eSata payload interface, or combinations thereof. Chassis connectors **1288**, **1289** can be used to attach the payload control module **128** to the robotic system **10**. The chassis connectors **1288**, **1289** can be thumbscrews. The payload control module **128** can be temporarily or permanently affixed to the robotic system **10**, for example, using welding, rivets, glue, magnets, temporary or permanent fasteners, or combinations thereof.

FIG. **48** illustrates that a payload control module **128** can be inserted in a payload interface **173**. The payload interface **173** can be located in the rear of the chassis frame **101**. The payload interface **173** can include a handle **1288** for pulling and/or ejecting the payload control module **128** from the alternate payload interface **173**, and carrying the payload control module **128**.

A video payload **190** can enable a remote user to view visual information on the remote operator control module **125**. The video payload **190** can have a payload camera **192** that can detect visible light, infrared (IR) radiation, ultraviolet (UV) radiation, or combinations thereof. The visual information can be anything within the visible, and/or IR and/or UV range of the payload camera **192** of the video payload **190** in the robotic system **10**, status information from the robotic system **10**, including video feeds, audio feeds, position, remaining battery life, system temperature, or any other suitable information, or combinations thereof. The remote operator control module **125** can include an antenna **196**, a video receiver **197**, and display interface **199** for displaying data received from a video payload **190**. The payload control module **128** can include an antenna **195** connected to an antenna port **129** (shown in FIGS. **12b** and **13**) connected to a video transmitter **194**. The payload control module **128** can include conditioning circuitry **193** for the payload camera **192**.

An audio payload **180** can enable a remote user to communicate with two-way audio communication from the remote operator control module **12** to anyone or anything within audible range of the audio payload **180** of robotic system **10**. The remote operator control module **125** can include a microphone **188** and speaker **189** for capturing audio to send to an audio payload **180** and playing back audio received from an audio payload **180**. The remote operator control module **125** can include an audio transceiver **186** and an antenna **179**. The payload control module **128** can include an antenna **187**, an audio transceiver **185**, conditioning circuitry **183**, a microphone **181**, and speaker **189**. As shown in FIGS. **12b** and **13** the robotic system can include at least one payload interface **171**, **172**, and **173**. A payload interface **171**, **172**, **173** can be attached to the chassis frame **101**, and/or the side plate **150** of the chassis **100**. The payload interfaces **171**, **172**, **173** can function as accessibility panels for service, maintenance, and inspection. When the payload interfaces **171**, **172**, **173** are not in use or are in use they can be covered with, respectively, the first, second and third interface covers **74**, **76** and **176**. The interface covers **74**, **76** and **176** can be made of aluminum sheet metal, a polymer with low moisture absorption properties such as ABS, or a clear material such as polycarbonate, crystal or combinations thereof. A cover **74**, **76** or **176** and/or a payload **170** can be attached to a payload interface **171**, **172**, **173** using machine screws, or any suitable fastener. The space between the cover **74**, **76** and **176** and/or a payload **170** and payload interfaces **171**, **172**, **173** can be sealed using a sealing device **177**. Except for the size and shape, the sealing device **177** can be identical to the sealing device **151** as described above. The payload interfaces **171**, **172**, **173** may include connections **174** to the controller module **120**.

FIGS. **12b** and **13** illustrate that a payload module may be attached to the chassis **100**. The payload can be a flat, "pickup truck style" cargo bed **170**, for example including a carrying handle **178**. One or more carrying handles **178** may be located on the bottom, side, or top of the chassis frame **100**. The carrying handles **178** can act as a roll bar. Supplies, tools, documents other suitable item to be placed in the robotic system **10** for transport, or combinations thereof can be placed in and/or secured to the cargo bed payload **170**.

FIGS. **12b** and **13** illustrate that the payload interface **172** can house an audio payload **180**. The audio payload **180** can be slid in from the top and fastened to the body frame. FIGS. **5a**, **8** and **10a** illustrate that the audio payload **180** can be attached to the top of the system **10**. The outside of the audio payload **180** can have a speaker grill, round microphone hole, antenna mount, and combinations thereof. The speaker can be

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recessed in the frame. The audio payload can transmit and/or receive audio. As shown in FIG. 58, the audio payload **180** can include at least one microphone **181**, **188**, at least one speaker **182**, **189** conditioning circuitry **183**, and an audio transmission link **184**.

The microphone **181**, **188** functions as a transducer to convert audio signals into electronic signals. The microphone **181**, **188** can be an electret microphone, laser microphone (e.g., for sound vibrations from smoke or fog in the air), a piezoelectric microphone, gel microphone, diaphragm microphone, a vibration detection microphone (e.g., a diaphragm microphone, a stethoscope, a gel/liquid sensor microphone (e.g., placed on the trachea to detect vocal vibrations) which can be touched to a metal or concrete surface, such as stairways, rails, or roads and detect vibrations and/or sounds), a parabolic microphone, a shotgun microphone, any other suitable microphone, or combinations thereof. The microphones **181** may be the same or a different type of microphone than the microphone **188**. The microphone **181**, **188** can be waterproof.

The speaker **182**, **189** can function as a transducer to output audio signals received from the audio transmission link. The speaker **182**, **189** can be sealed and waterproof. The speaker **182**, **189** may be replaced or bypassed with a headphone jack to output to headphones, audio recording, other suitable audio output, or combinations thereof.

The conditioning circuitry **183** can function to amplify and/or filter the audio signals. The signal received from the microphone **181** can be amplified before being transmitted by the audio transmission link **184**. The signal output to the speaker **182**, **189** can be passed through a pre-amplifier, and then a speaker amplifier before being output by the speaker **182**, **189**. The conditioning circuitry **183** can be integrated into the audio payload module **180**. The conditioning circuitry **183** may be integrated in the operator control unit **126**, and/or in the control module **120**.

The audio transmission link **184** can transmit the audio signal received from the microphone **181** to an operator control unit **126**, and transmit audio received from a microphone at the operator control unit **126** to the speaker **182** in the audio payload module **180**. The audio transmission link **184** can be a wireless transmission link, a wired transmission link, any other suitable transmission link, or combinations thereof. The audio transmission link **184** can be an analog FM transmission link, a digital transmission link, wireless networking link, IEEE 1394 link, USB 1.0 2.0 3.0 link, any other suitable link, or combinations thereof. The audio transmission link **184** can include at least one audio transmitter and one audio receiver, for example two audio transceivers **185**, **186**, and antennas **187**. The audio transmission link **184** can be integrated in the audio payload module **180** of the robotic system, integrated in the control module **120**, or combinations thereof. The antenna **187** can be mounted on the audio payload module **180**. The antenna **187** can be attached to a control module antenna port **127**, **129**. The audio transmission link **184** is not present, and the audio is recorded for later retrieval and playback.

The audio transceiver **185**, **186** can transmit the audio data using approximately a 433 MHz carrier frequency. The antennas **187** can be rugged and coated in rubber. The antennas **187** can be optimized to transmit and receive data on an approximately 433 MHz carrier, and/or transmit and receive data in any suitable frequency range.

The data transmissions between the audio payload **180** and the user controller **125** may interfere with the transmission of control signals between the user controller **125** and the control module **120** due to the near overlap of carrier frequency

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ranges for control data and audio data. The control data may be considered to be of higher importance than the audio data transmitted between the remote user controller **125** and the audio payload **180**, but alternatively the audio data may be of higher importance (for example on a surveillance mission, where the robot system is primarily stationary and listening). To avoid interference, a time division multiplexing scheme can be used, the simplest example being a half duplex communication mode; for example, the robotic system can turn off the audio data transmission partially or completely while the robot system **10** is receiving control data and/or in motion, thus removing any possibility of interference between the audio data transmission and the control signals for the robot system. The control data may be partially or completely disabled while the audio data is transmitted. Additional multiplexing schemes may be used to prevent or reduce interference between control signal transmissions, audio data transmissions, video data transmissions, other payload data transmissions, and other (possibly external) sources of interference.

FIGS. **13** and **59** illustrate that the payload interface **171** can house a video payload module **190** that can include the payload camera **192**, a lighting system **191**, conditioning circuitry **193**, a video transmission link **198**, and a display **199**. The payload interface **171** can be protected with a clear-panel cover **176**, and sealed with a sealing device **177** to seal the payload interface **171** and make the payload interface **171** waterproof and/or dustproof, while simultaneously allowing a video payload to capture video. The panel cover **176** can be made from polycarbonate, crystal, or combinations thereof. The payload interface **171** may be uncovered, protected by shuttering, covering with mesh, covering with crystal, or combinations thereof.

FIGS. **49** and **50** illustrate that the audio payload module **180** can be integral with the video payload module **190**. The panel cover **176** can be sealed into the chassis **1001** using a sealing device **177**, sealing screws **1770**, **1771**, or combinations thereof. The sealing device **177** can be an o-ring. The sealing screws **1770**, **1771** can be o-ring sealed screws. The speakers **182**, and/or the microphone **181** can be attached with one or more glues and/or fasteners, such as an epoxy. The speakers **182** can emit a volume. The speakers **182** can be located behind the panel cover **176**. For example sound emitted by the speakers **182** may need to pass through the panel cover **176** before being broadcast to the environment outside of the system **10**.

FIG. **51** illustrates that the payload camera **192** can be attached to brackets **1772**, **1773**. The payload camera **192** can be moved or shifted back. Moving the payload camera **192** back can improve airflow, enable electronics heatsinks for electronics, such as an LED lighting system, on the board. The payload camera **192** can be positioned about 6 mm from the front of the cover **176**.

FIGS. **52a** and **53** illustrate that a bezel cover **1760** can be attached to the front or rear of the system **10**. The bezel cover **1760** can include audio holes or perforations **1780** positioned in front of and in unobstructed fluid or audio communication with the speakers **1761**, microphones **1762**, or combinations thereof. The bezel cover **1760** can have, perforations positioned directly in front of sensors or transducers in or on the system **10** such as cameras **1763**, lights **1764**, lasers, infrared lights, displays, chemical sensors, pressure sensors, scanning laser sensors, sweeping laser light (e.g. for face scanning, room scanning, fingerprint scanning, footprint scanning or combinations thereof), other, or combinations thereof.

FIG. **53** illustrates that the bezel cover **1760** can be attached to one, two or more wire guard bumpers **1765**, **1766**. The

bezel cover **1760** can be attached to a transparent, translucent or opaque bladder filled with a fluid such as a gas, for example air, or a liquid such as water, an electromagnet, a polymer bumper, or combinations thereof. The wire guard bumpers **1765**, **1766** can be bent or twisted. For example, the wire guard bumpers can protect the bezel cover **1760** from impacts with external objects, and reduce or remove interference and obstructions from input/output devices on the robotic system **10** (e.g., minimizing the debris that enters the perforations **1780**).

The bezel cover **1760** can include a display screen. The display screen can be an LED or an OLED screen, E-INK screen or any other suitable screen. The display screen can display images and/or text and/or virtual faces. For example, the display screen can display a red cross symbol when delivering medical supplies, and/or display the face of the operator such that a subject the robotic system encounters can possibly recognize the operator. The display screen can be used for video chatting, for example between the payload camera **192** and display screen on the bezel cover **1760**, and the remote operator control module **125**. The video chatting capabilities can be integrated with video chat products such as Skype or Apple FaceTime.

The lighting **191** of the video payload module **190** can be both visible and infrared light, for example visible and infrared Light Emitting Diodes (LEDs), any suitable LEDs, any incandescent, fluorescent, phosphorescent (glow in the dark), chemical, combustion, laser, or other light source, or combinations thereof. The lighting **191** can be controlled via the microprocessor **121** of the control module **120**, controlled by an additional microprocessor, or combinations thereof. The microprocessor **121** of the control module **120** can generate on, off, or variable dimming level signals for the lighting system **191**. The control signals for the lighting **191** may be transmitted from the operator control unit **126** to the microprocessor **121**. The lighting **191** may be automatically turned on and off by the microprocessor **121** in response to ambient light levels detected by an ambient light sensor.

The payload camera **192** can capture image data. The payload camera **192** can be one, two or more cameras, for example an analog video camera capable of detecting both infrared and visible light, a digital video camera, a still camera, a film camera, a forward looking infrared (FLIR) camera, any other suitable camera, or combinations thereof. The payload camera **192** can be adapted to feed a video signal into conditioning circuitry **193**.

The conditioning circuitry **193** can provide signal processing and/or signal switching, and/or filtering to the video signal. The conditioning circuitry **193** can include video feed switching and/or video feed overlay functionality, for example the conditioning circuitry **193** can have a video feed overlay chip that can be configured to switch and/or overlay video feed. The video feed overlay functions to combine display text and/or images in an overlay in the video feed signal, for example identifying the camera view, identifying the video feed, displaying battery life, sensor output data, positioning data, or any other suitable application. The conditioning circuitry **193** can include a video feed switch, which can be controlled by the microprocessor **121** of the main control module **120**. The conditioning circuitry **193** may include filtering or amplifying circuitry to improve the quality of the video feed. The conditioning circuitry **193** can be integrated in the payload module, but may alternatively be integrated in the operator control unit **126**, or anywhere in the control module **120**.

The video transmission link **198** can transmit the video signal to an operator control unit **126**. The video transmission

link **198** can be a wireless transmission link, a wired transmission link, other suitable transmission link, or combinations thereof. The video transmission link **198** can include a video transmitter **194**, antennas **195**, **196**, and a video receiver **197**. The video transmission link **198** can be integrated in the control module **120** of the robotic system, and can be integrated in the payload module **190**. The video transmission link **198** can be an analog FM transmission link, a digital transmission link, wireless networking link, IEEE 1394 link, USB 1.0 2.0 3.0 link, other suitable link, or combinations thereof.

The video feed may be recorded and/or transmitted via a video transmission link. The video transmitter **194** can convert a video signal into a communications signal and transmit the communications signal to a video receiver **197** using an antenna **195**. The video receiver **197** can receive a communications signal from the video transmitter **194** via an antenna **196**, and convert the communications signal into a video feed and output the video feed to a display **199**.

The antennas **195**, **196** can be adapted to receive signals in the 900-1100 MHz range. The antennas **195**, **196** can be coated with rubber and ruggedized. The antennas can be rubber duck antennas. The antennas can be shear resistant. The antennas can be joined to the body **20** at a hinged or otherwise articulatable mount. The antenna **195** for the video transmitter **194** can be connected to one of the antenna ports **127**, **129** as shown in FIGS. **12b** and **13**.

The display **199** can display the video feed from the payload camera **192** and any overlaid information that may be included in the video feed from the conditioning circuitry **193**. The display can be an LCD screen, an LED screen, an OLED screen, a TFT screen, other suitable screen, or combinations thereof.

The transmission frequencies of the video data, audio data, and control data can be approximately 900-1100 MHz, 433 MHz, and 480 MHz, respectively. These ranges for the three separate data channels can minimize or prevent interference. The video signal can be transmitted at a high enough frequency to sustain a high data rate and avoid any interference with the audio and control signals. In certain operating conditions, the control data and the audio data may interfere with each other. The control module **120** can turn off the audio payload **180** while control signals can be received in the user control module **126**.

Payload modules may include one, two or more sensors, input and/or output devices, tools, equipment and/or supplies including still cameras, film based cameras, forward looking infrared cameras, boom cameras, fisheye cameras, pan-tilt-zoom camera systems, light intensity sensors, electromagnetic radiation sensors, sound recorders, laser range finders, navigation systems, Global Positioning System (GPS) sensors, depth sensors, pressure sensors, radiation sensors, chemical sensors, pathological sensors, biological sensors, fire extinguishers, chemical decontamination systems, medical equipment, medical supplies, food supplies, water supplies, construction supplies, defibrillators, lethal and non-lethal weapons or munitions, electroshock weapons (e.g., Tasers by Taser International, Inc. of Scottsdale, Ariz.), explosive disruptors, robotic arms, equipment carriers, equipment actuators, spike strip launchers, caltrop droppers, precision turret systems, robotic hooks, actuated pokers, pressurized blowers, compressed gas (e.g., air, carbon dioxide, nitrogen), blower fans, vacuum devices, additional batteries, biometric devices, or combinations thereof. Payloads may include door opening devices battering rams, prybars, door-knob interfaces, lockpicking systems), marsupials, marsupial water vessels, UGV's or UAV's, toys, construction equip-

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ment, farming equipment, high voltage repair equipment, personal assistance devices, a 3-dimension camera, information transmission systems (e.g., RF modules with additional antennas), radio signal disruptors such as signal jammers or shape charges, x-ray visualization systems, manipulator aims, 360-degree cameras, offloaded processors for data processing (e.g., to supplement the processors) on board the such as video processing and/or used for tiered processing, data storage such as hard drives or flash memory, or combinations thereof).

FIG. 55 illustrates that a camera payload 1920 can have the payload camera 192. The camera payload 1920 can have actuators attached to the payload camera 192 that can be configured to pan and tilt the payload camera 192. The payload camera 192 can be configured to zoom in and out, for example with a motorized, adjustable lens. The camera payload 1920 can have a payload base 1926 attached to a payload cage 1924 having a rollbar 1925. The payload base 1926 can be removably attached to the remainder of the system 10, such as to the chassis 1001, via at least one module attachment element, such as module attachment screws 1927, at each corner of the payload base 1926. The payload cage 1924 and/or the rollbar 1925 and/or the payload base 1926 can encircle the payload camera 192.

The camera payload 1920 can have a bubble dome 1921. The bubble dome 1921 can have a solid panel of plastic. The bubble dome 1921 can be attached to the payload cage 1924, such as to the rollbar 1925, and/or to the base 1926. The bubble dome 1921 and the payload cage 1924 and/or the payload base 1926 can enclose the payload camera 192. The bubble dome 1921 and/or the payload cage 1924 and/or the payload base 1926 can protect the mechanical circuitry and the payload camera 192 from contaminants such as dust, sand, and liquids. The contaminants can impair the visibility, or scratch a lens of the payload camera 192, and/or impair the range of motion of the payload camera 192. The rollbar 1922 can protect the bubble dome 1921 from damage from impact-sor trauma, such as scratches and cracks.

The payload camera 192 can be a full color camera. The camera payload 1920 can pan the payload camera 192, such as by rotating the payload camera 192 laterally, as shown by arrow 1928. The payload camera 192 can be rotated laterally from a fixed, unrotatable configuration to an unrestricted, repeatable 360° rotation (i.e., rotating over 360° with no maximum), more narrowly less than or equal to about 360 degrees, yet more narrowly less than or equal to about 180°. The camera payload 1920 can tilt the payload camera 192, such as by rotating the payload camera 192 vertically, as shown by arrow 1929. The payload camera can be rotated vertically from a fixed, unrotatable configuration to an unrestricted, repeatable 360° rotation (i.e., rotating over 360° with no maximum), more narrowly equal to or greater than about 180 degrees. The payload camera 192 can have a digital zoom of approximately 100x-120x.

FIGS. 11 and 56 illustrate that the drive module 130 can be configured to deliver mechanical energy to the mobility device 200. The drive module 130 can be mechanically linked to the mobility device 200. For example, the drive module 130 can be linked to the mobility device 200 using a pinion 131 adapted to rotate a ring gear 155, and the ring gear 155 can be adapted to rotate a rotatable axle sleeve 153 connected to a mobility device 200.

FIG. 56 illustrates that the drive module 130 can include at least one gearbox 132, at least one motor 134, and at least one motor controller 136. As shown in FIG. 22, the drive module 130 can include a cooling device 138. The drive module 130 can be located near the center of the chassis frame 101, for

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example in an inner wall of a chassis frame compartment 103, which improves stability. The chassis 101 can be made of a heat absorbing material, such as a metal, the drive module 130 can be in contact or close proximity with a wall of the chassis frame 101, which can allow the chassis frame 101 to provide passive cooling functionality, functioning as a heat sink and transferring heat away from the drive module 130. Additional passive cooling may be integrated into the drive module mount, either on the drive module 130 or in the chassis frame 101.

The motor controller 136 functions to provide power and control signals to the motor 134. The motor controller 136 can be adapted to receive power from a power supply 110 and control signals from a control module 120. In an alternative variation, the motor controller 136 may also be adapted to control a cooling system 138. The motor controller 136 can be a brushless motor controller, for example a brushless motor controller with a digital control interface, an open loop (or non-feedback) motor controller or combinations thereof.

The motor 134 functions to provide mechanical power to the gearbox 132. The motor 134 can be adapted to receive control signals and power from the motor controller 136. The motor 134 can be an electric motor, a fuel powered engine, or combinations thereof. The motor 134 can be a brushless motor, for example a brushless motor with Hall effect sensors, an open loop controlled motor, a brushless motor, or combinations thereof. The Hall effect sensors can provide good low speed control and are more energy efficient, the open loop mode (without using hall effect sensors) requires more power.

The gearbox 132 can adapt the mechanical output of the motor 134 to a higher or lower output for the mobility device 200. The gearbox 132 can be an interchangeable gearbox, and may be adjusted for different mobility devices (e.g. different sized wheels), different power/torque requirements, or combinations thereof. The gearbox 132 can be connected to a pinion 131 adapted to rotate other gears connected to a mobility device 200, and/or be connected to a mobility device 200 directly.

The drive module 130 can include a cooling device 138. The cooling device 138 may regulate the temperature of components within the chassis 100. For example, the cooling device 138 can regulate the temperature of the components in the drive module 130. The cooling device 138 can be a cooling fan, for example an electric cooling fan, a heatsink, a water-cooling system, a refrigeration system, or combinations thereof. At least one cooling fan can be mounted on the motor, such that the airflow generated can flow over and around the motor to regulate the temperature and provide targeted cooling. Fans may also provide general system cooling, and/or cooling to other elements in the chassis 100.

FIGS. 60 and -61, illustrate that the system 10 can have a front intake port 1386a, a side or rear chassis heatsink 1382, and at least one exhaust fan 1381. The exhaust fan 1381 can have one or more top, side, bottom or rear exhaust vents or ports 1388a, 1388b, 1388c, and 1388d, respectively. The exhaust fan 1381 can force convection over the side or rear heatsink 1382. For example, the exhaust fan 1381 can pump, blow or draw a fluid (e.g., ambient air when the system 10 is on ground, and ambient water when the system 10 is in water) through the front intake port 1386a, through an internal or external cooling channel 1393 and across vanes or fins 1384 of the side or rear chassis heatsink 1382. Heated air around the chassis heatsink 1382 can be expelled through the top exhaust vent 1388a, as shown in FIG. X2, and/or expelled through at least one side exhaust vent 1388b, as shown in FIG. X3.

FIG. 62 illustrates that the system 10 can have a bottom intake port 1386c on the bottom of the system 10, a top intake

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port **1386a** on the top of the robotic system **10**, side or rear intake ports on the side or rear of the system **10**, or combinations thereof. A fluid circulation device such as the exhaust fan **1381** can draw, as shown by arrows, an ambient fluid, such as ambient air or water, into the bottom intake port **1386c**, across the chassis heatsink **1382**, and expel the heated air out the top or the bottom of the robotic system **10** (e.g., through the top exhaust port **1388c**. The exhaust fan **1381** can be reversed, and the air can be drawn in through the top exhaust port **1388c** and exhausted through the bottom intake port **1386b**.

FIG. **63** illustrates that the rear chassis heatsink **1382** can be used to dissipate heat from inside of the chassis **1001**. The exhaust fan **1381** can be attached to the outside of the rear chassis heatsink **1382**. The ambient fluid can passively or actively (e.g., when blown by the fan) pass over vanes on the heatsink **1382**.

FIG. **64** illustrates that a side chassis heatsink **1382** can conduct heat from inside the chassis **1001** to outside the chassis **1001**. The exhaust fan **1381** can be attached to the outside of the side chassis heatsink **1382** to force the fluid of the environment through the side chassis heatsink **1382**. FIG. **65** illustrates that a reservoir **1383** can hold a liquid or gas, for example water. The reservoir **1383** can evaporate the liquid or gas through an exhaust vent or port **1388** as heat is absorbed by the contents of the reservoir **1383**. The reservoir **1383** can have one or more reservoir vents, for example, configured to vent pressurized vapor and/or pressurized hot gas. The system **10** with the reservoir **1383** can have or be absent of exhaust fans **1381**, or filters.

FIG. **66** illustrates that the system **10** can have one or more internal or external heat pipes **1390** having cool ends **1391** and hot ends **1392**. The heat pipes **1390** can contain a gas or liquid such as water, alcohol, or combinations thereof. The heat pipes **1390** can be fabricated from aluminum, copper, steel, iron, ceramic, or combinations thereof. The cool ends **1391** can be attached to the chassis **1001**, one or more chassis heatsinks **1382**, motor heatsinks **1258**. The hot ends **1392** can be attached to the control module **120**, including the microprocessors **121** and the control board, and power modules **122**, the power board, the drive module **130** including the gearboxes **132**, motors **134**, and motor controllers **136**, power supply **110** including the batteries, or combinations thereof. The heat pipes **1390** can pipe or transfer heat from the hot ends **1392** at specific devices or areas in the robotic system **10** which can be sensitive to ambient operating temperatures—e.g., from the control module **120**, microprocessors **121**, control board, power modules **122**, power board, drive module **130**, gearboxes **132**, motors **134**, motor controllers **136**, power supply **110**, and batteries, combinations thereof—to the cool ends **1391**—e.g., to the chassis **1001**, chassis or motor heatsinks **1382** or **1258**, or combinations thereof, for example to cool the hot ends **1392** and the elements located at the hot ends **1392**. The exhaust fans **1381** may draw other gasses. As described herein, the exhaust fans **1381** can be combined with or substitute with or for pumps, reservoirs, pressurized cartridges, flow generating devices for water or other liquids or gasses, or combinations thereof.

FIG. **67** illustrates that the chassis **100** can have a waterproof connector **1385**. The waterproof connector **1385** can connect to the exhaust fan **1381**. The exhaust fan **1381** can be located on the outside of the chassis **100**. The waterproof connector **1385** can deliver and receive power and control signals to and from the exhaust fan **1381** and the power board and/or control boards **120** inside the chassis **100** of the robotic system **10**.

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FIG. **52d** illustrates that a rear chassis heatsink **1388d** and/or exhaust fan **1381** can be mounted on the rear of the robotic system **10**. A rear heatsink cover **1389a** can be attached to the rear end of the chassis **100**. The rear chassis heatsink **1388d** and/or exhaust fan **1381** can be covered and protected with a rear heatsink cover **1388**.

FIG. **52c** illustrates that a side chassis heatsink **1388b** and/or exhaust fan **1381** mounted on a side of the robotic system **10** can be covered with a side heatsink cover **1389b**. The rear and side heatsink covers **1389a** and **1389b** can align, support and protect the exhaust fan **1381** and the chassis heatsink **1388** and fan attachments from damage. The rear and side heatsink covers **1389a** and **1389b** can be removably attached to the chassis **100**. For example, the heatsink covers **1389**, chassis heatsinks **1388** and exhaust fans **1381** can be cleaned, repaired and replaced.

A mobility assistance module **140** can transfer mechanical energy to a mobility assistance device **300**. As shown in FIG. **57**, the mobility assistance module **140** can include a motor controller **146**, a motor **144**, a safety coupling **143**, a gearbox **142**, or combinations thereof.

Except as noted herein, the motor controller **146**, the motor **144** and the gearbox **142** can be identical to the motor controller **136**, the motor **134**, and the gearbox **132** of the drive module **130**. The gearbox **142** can be attached to a pinion **141**, and the pinion **141** is adapted to rotate a ring gear **142** adapted to rotate an axle **149**.

The safety coupling **143**, functions to decouple the axle shaft **149** from the actuation of the motor **144** in the event of an impact or shock to the mobility assistance device **300**. As shown in FIGS. **68** and **69**, the mobility assistance device **300** can be a flipper **301**, and the flipper **301** may be popped, as shown by arrow **400** in FIG. **28**, for example with a torque from about 15 Nm (11 lb.-ft.) to about 145 Nm (107 lb.-ft.), more narrowly from about 30 Nm (22 lb.-ft.) to about 125 Nm (92.2 lb.-ft.), for example about 100 Nm (74 lb.-ft.) or about 30 Nm (22 lb.-ft.) of torque at the axis of rotation. The flipper **301** can be popped, slammed, or hit against a hard surface or object in order to cause the safety coupling to decouple and allow the flippers to be folded into a compact configuration for storage. The safety coupling **143** can be a ball detent, a torque limiter, an override coupling, any other decouplable mechanism, or combinations thereof. The safety coupling **143** can include an actuator to automatic-re-engage functionality, an actuated and/or manual re-engage function, which may use a solenoid actuator to re-engage the safety coupling **143**, or combinations thereof.

The device can have a clutch, or no clutch, in mechanical communication between the engine and the axles **149** and/or **169**. A continuous amount of force can be required to fold the flipper into a storage configuration (e.g., with a clutch), or a single sharp impact can cause a release of the axle **149** from the actuation of the motor **144** (e.g., with a safety coupling). The manually actuated and electronically actuated mobility assistance devices can disconnect the mobility device to go from a ready position to a stowed position, using a mechanical release (such as a pin or a ball detent, brake or clutch, tensioner). This can remove the need for position feedback and autonomous rotation to a stowed position. The release can be electronically activated. The release may be activated by motion, impact, impulse, the press of a button pulling a lever, actuation by a motor, or any combination thereof. The sensitivity of the activations can be adjusted, as can the number of activations needed to release.

As shown in FIG. **11**, the mobility device **200** can enable the robotic system **10** to move in the environment, which may include land, air, water, underground, underwater, outer

space, asteroids, comets, other planets, other galaxies and moons. As shown in FIGS. 15 and 16, the mobility device 200 can be a track 210 driven by at least one track drive pulley 220 and guided by at least one track guide 230. The mobility device 200 may be a set of wheels, skis, skates, propellers, wings, sails, blades, balloons, floats, paddles, oars, flippers, corkscrews, winches, pressure tanks, rockets, a hover system, the tracks described above, or combinations thereof.

As shown in FIGS. 32 and 33, the mobility device 200 can include two track drive pulleys 220, 221 and at least one-track guide 230 for each track 210. The robotic system 10 can include two mobility devices 200, for example two tracks 210, one on each side of the chassis 100, or a single track 210. The mobility device 200 can include a drive pulley track cap 240.

The track 210 can link together the motion of the track drive pulleys 220, 221. The track may provide great mobility over a wide variety of terrains. The tracks can be replaced with wheels alone. The track 210 can be made of a polymer, for example a Thermo Plastic Urethane (TPU), other polymers, elastomers, metal mesh, carbon fiber based materials, metal links, metal-banded rubber, leather, or combinations thereof.

The track 210 can be manufactured using at least one fixed length of injection molded track and then bonding the ends of at least one length together using a solvent, to create a continuous track 210 at a low cost. Solvents may be used for bonding polymer track bands or any other polymer suitable for manufacturing track bands. Bonding the track bands may include using glue, a fastener such as a staple, rivet, or snap, or using a thermal process to melt the ends of at least one band together. The track 210 can be molded as a single piece of continuous connected track.

The track 210 can be molded with multiple layers. An inner material can be used with a mold to produce a base layer of the track 210 and an outer material can be overmolded to produce an outer layer integrated with the outer surface of the base layer. The base layer of the track 210 can be a different color than the outer layer of the track 210. When the outer layer wears, the color of the base layer can show through to the outside of the track 210. The visibility of the color of the base layer can be a wear indicator for the track 210. The expected remaining life of the track 210, and/or when it is time to replace the track 210 can be indicated by the amount of color of the base layer visible. The base layer can include the cleats either molded into or attached to the track. The wear leveling can be tapered, such that as an area wears more, the color variation between the base layer and the outer layer increases.

As shown in FIGS. 32 and 33, the outside of the track band 210 can include outside nubs 211, 212. The outside nubs 211 and 212 can increase traction on a variety of surfaces, for example when the system 10 climbs over obstacles. The outside nubs 211, 212 can be substantially the width of the track, arranged perpendicular to motion vector of the track 210. The outside nubs can be any suitable width, and arranged in any suitable track pattern. The outside nubs 211, 212 can be uniformly or non-uniformly spaced on the track band 210.

The track 210 may be modified or adapted for special purposes instead of the regularly spaced outside nubs. The track 210 can have application-enhancing elements such as suction cups for climbing walls, spikes to improve traction on ice, or any other suitable modification or addition to the track 210 for any other suitable purpose, or combinations thereof.

FIGS. 32 and 69 illustrate that the inside of the track 210 can include inside nubs 216, 217, 218 that can keep the track 210 aligned on the track drive pulleys 220, 221 and the track guide 230. The outside edge of the inside nubs 216, 217, 218

can be rounded from the outer edge of the track 210 toward the inside of the track 210. The outside edge of the inside nubs 216, 217, 218 can be squares, triangles, cylinders, or any other suitable shape. The inside nubs 216, 217, 218 can be uniformly or non-uniformly spaced around the inside edge of the track 210.

FIG. 68 illustrates that the inside nubs 216, 217, 218 can be spaced a fixed distance from the outer edge of the track 210 along an axis perpendicular to the motion vector of the track 210. The spacing between inside nubs 216, 217, 218 along an axis perpendicular to the motion vector of the track 210 can be the width of the track drive pulley 220, and the track guide 230. The inside of the track 210 can include a depression 213. The depression 213 can increase the grip of ridges 214 on a track drive pulley 220. The insides of the track 210 can have a smooth area 215, for example having no depressions 213. The inside of the tracks can be entirely smooth, have repeated depressions along the entire length, or combinations thereof.

The track drive pulley 220 can turn the track 210. At least one track drive pulley 220 on the track 210 can be adapted to be actuated by a rotatable axle sleeve 153 through a hole in the side plate 150 of the chassis 100 connected to the drive module 130 either directly or through a series of gears inside the chassis 100. The track drive pulley can have nubs which can interface with divots on the inside of the track. The track drive pulley can be configured to grab the track and/or keep the track aligned on the track drive pulleys.

FIG. 32 illustrates that the pins 154 can be used to mechanically link or fix the rotatable axle sleeve 153 and the track drive pulley 220, 221, but other interfaces, techniques or parts may be used to mechanically link the rotatable axle sleeve 153 and the track drive pulley 220, 221. For example, glue, fastener, clips, or combinations thereof can be used to link the rotatable axle sleeve 153 and the track drive pulley 220, 221.

The track drive pulley 220 can be assembled from two components, an inner wheel hub 222, 223, and an outer wheel 224, 225. The track drive pulley 220 may be manufactured as a single, integrated component, or assembled from any number of components. The inner wheel hub 222, 223 can be made of nylon, other polymers, metal, carbon fiber, concrete, cardboard, wood, any other suitable material, or combinations thereof. The outer wheel 224, 225 can be made from TPU, Santoprene, other polymers, elastomer, or elastomer/polymer blend, metal, or combinations thereof. The inner wheel hub 222, 223 can be manufactured using a molding process, machined, cast, extruded, stamped, any other suitable method of manufacture, or combinations thereof. The outer wheel 224, 225 can be manufactured using an injection molding process, machined, cast, extruded, stamped, or combinations thereof.

Torquing a softer polymer with an axle made of a harder material, such as a metal, may tear the polymer at higher torque levels. The combination of a metal rotatable axle sleeve 153 (or a metal axle 149) adapted to rotate a rigid polymer inner wheel hub 222, 223 attached to a polymer (e.g., a polymer softer than the rigid polymer inner wheel hub) outer wheel hub 224, 225, can enable a high torque mechanical output to be distributed to a softer polymer outer wheel with shock and/or impact absorption, and improve durability at the interface between the metal and polymer. For example, the modulus of elasticity of the inner wheel hubs 222 and 223 can be about 280,000 to 420,000. The modulus of elasticity of the outer wheel hubs 224 and 225 can be about 8,000 to 20,000. The modulus of elasticity of the axles 149, 169 can be about 800,000 to 8,000,000. The ratio of the modulus of elasticity of the inner wheel hub 222 and 223 to the axle 149, 169 can be from about 0.5 to about 100, more narrowly from

about 1 to about 29, yet more narrowly from about 1.9 to about 1, for example about 10. The ratio of the modulus of elasticity of the outer wheel hub **224** and **225** to the inner wheel hub **222** and **223** can be from about 0.5 to about 100, more narrowly from about 1 to about 50, yet more narrowly from about 1.9 to about 11, for example about 10. The surface area of contact between the axle and the inner wheel hubs **222** and **223** can be greater than or less than the surface area of contact between the inner wheel hubs **222** and **223** and the outer wheel hubs **224** and **225**. The inner wheel hubs **222**, **223** can interface with the outer wheel hubs **224**, **225** by overmolding. Overmolding can include making the inner wheel hubs **222**, **223** of an inner wheel hub material, making the outer wheel hub from an outer wheel hub material, where the inner wheel hub material is harder than the outer wheel hub material, and wherein the outer wheel hub is overmolded onto the inner wheel hub.

The inner wheel hub **222**, **223** can be assembled from two components fastened together. The components of the inner wheel hub **222**, **223** can be wheel hub plates **222**, **223** fastened together with self tapping screws, nuts and bolts, interlocking snaps, rivets, glue, any other suitable fastener, or combinations thereof.

FIGS. **68** and **69** illustrate that the wheel hub plates **222**, **223** can be fastened together in such a manner that they interlock (forming an interlocking hub) around a portion of the outer wheel **224**, **225**, such that the inner wheel **222**, **223**, and the outer wheel **224**, **225** can rotate together.

FIGS. **32** and **69** illustrate that one of the wheel hub plates **223** can include a keyed interface, for example a hex-shaped keyed interface, adapted to rotate a shaft connected to a mobility assistance device **300**. The other inner wheel hub plate **222** can include a bearing to interface between an axle **149** and the inside of the track drive pulley **220**. The inner wheel hub plate **222** can include an interface **226** for the rotating axle sleeve **153**. The inner wheel hub plate can be connected to the rotating axle sleeve **153** using pins **154**, a connection to an axle **149**, any other suitable actuator, or combinations thereof. The inner wheel hub plate **222** can include a ball bearing **219** located between the center of the inner wheel hub plate **222** and the axle **149**.

FIGS. **5** and **6** illustrate that the outer wheel **224**, **225** can include at least one tier of supporting members arranged radially or substantially radially, from the inner wheel hub **222**, **223** to the outer rim of the outer wheel **224**, **225**. The outer wheel **224**, **225** can include 2 tiers of supporting members arranged radially, where the first tier of supporting members **222** connects the inner wheel hub **222**, **223** to an intermediate rim, and the second tier of supporting members connects the intermediate rim with the outer rim of the outer wheel **224**, **225**. The supporting members can be spaced evenly around the outer wheel **224**, **225**, or be spaced unevenly or in any suitable fashion. The supporting members can be of the same or substantially similar thickness to the outer rim of the outer wheel **224**, **225**, and/or any suitable thickness. Each outer wheel **224**, **225** can have one, two, three or more tiers of supporting members **221**, **222**. The supporting members (e.g., two or three) can reduce the weight, material and cost of the outer wheel **224**, **225** of the track drive pulley **220**, **221** and increase flexibility and shock absorption, while creating larger spaces within the outer wheel **224**, **225** to improve the tolerance of the track drive pulley **220**, **221** to foreign objects such as rocks, grass, twigs, which may get caught in the spaces between the supporting members of the outer wheel **224**, **225**, and improve the ability of the track drive pulley **220**, **221** to flex if a foreign object (e.g., a pebble and/or a twig) is introduced in between the outer wheel **224**,

225 of a track drive pulley **220**, **221** and the track **210**. When a foreign object is caught between the track **210** and the track drive pulley **220**, **221**, the pressure from both the outer wheel **224**, **225** of the track drive pulley **220**, **221** flexing and the track **210** flexing and pressing on the foreign object between the track **210** and the outer wheel **224**, **225** can be large enough to squeeze and throw the foreign object out from between the track **210** and the outer wheel **224**, **225** of the track drive pulley **220**, **221** and can be a self-cleaning functionality for the track **210**, which can reduce or eliminate the need for manual track cleaning and a track cleaning system. The track and/or track drive pulley or other elements can be made from a non-reinforced TPU, TPE or Santoprene flexible material, as well as other rubbers or flexible thermoplastics.

The self-cleaning function can allow the tracks **210** to be run looser against the track drive pulleys **220**, **221**. The tension of the track (which may vary with temperature) can be evaluated relative to the track's position with respect to the wheel cap. The outside edge of the track at the most contracted state of the track (i.e., highest tension) can be outside the radius of the wheel cap (e.g., to prevent the wheel cap from rolling against the ground instead of the track rolling against the ground), for example including the nubs on the track. At the expanded state of the track (i.e., lowest tension), the cap and sideplate body can be no larger than the inside of the track (e.g., enough to hold the track on the track drive pulley)] The track **210** can have a track tension from about 0.4 N (0.1 lb.) to about 534 (120 lb.). The outer wheel **224**, **225** can include at least one ridge **214**. The ridge **214** can interface with the depression **213** in the track **210** and improve traction of the track drive pulley **220** on the track **210**. The ridge **214** can be substantially uniformly spaced around the outer wheel **224**, **225**, and parallel to the axis of rotation of the outer wheel **224**, **225**, but any suitable pattern of ridges may be used. The ridge **214** can be mated to at least one depression **213** in the track **210**, but may alternatively be any suitable shape.

During extreme operating conditions or rough terrain, for example, one or more tracks **210** may be dislodged from or thrown off the track drive pulleys **220**. The track guide **230** can keep the track **210** aligned on the track drive pulley **220** and realign the track **210**, for example, if the track **210** is of the track drive pulley **220** or the tracks alignment with the track drive pulley **220** is maladjusted. The track guide **230** can be attached to the side plate **150** of the chassis **100**, for example the track guide **230** can be mounted on the side plate **150** with machine screws, fastened to the side plate **150** with rivets, glue, interlocking parts or other suitable fastener, or combinations thereof. The track guide **230** may be integrated into the side plate **150** as a single piece for manufacture. The track guide **230** may be fused with the side plate **150**. The track guide **230** can guide the track **210** as the track **210** passes above and/or below the track guide **230**. The track guide **230** can guide the track **210** as the track **210** passes above and/or below the track guide **230**. The track guide **230** can be made of lubricated nylon, another polymers, metal, carbon fiber, concrete, cardboard, wood, any other suitable material, or combinations thereof. The track guide **230** can be injection molded, cast, extruded, machined, stamped, cut, any other suitable method of manufacture, or combinations thereof.

FIGS. **30** and **33** illustrate that the side plate **150** of the chassis **100** can assist the track guide **230** or act independently in maintaining the alignment of the track **210** on the track drive pulleys **220**. The side plate **150** can be slightly larger than the inside diameter of the track **210** when the track **210** can be stretched over the track guide **230** and the robot drive pulleys **220**. The flanging of the side plate **150** relative the track **210** can interference fit against the track **210** prevent the

track **210** from being thrown or otherwise moved onto the chassis **100** and, for example, getting stuck between the drive pulleys **220** and the chassis **100**. The side plate **150** can be slightly larger than the inside diameter of the track **210**, and smaller than the outside diameter of the track **210**. The side-plate can protrude from about 1 mm (0.04 in.) to about 2 mm (0.08 in.) beyond the inside diameter of the track. The side-plate **150** can provide additional track guidance. The robotic system **10** may operate while inverted.

FIGS. **11**, **62** through **65**, **68** and **69** illustrate that the mobility assistance device **300** can assist the robotic system **10** in particular situations and/or special terrain, for example climbing over objects, climbing up stairs, or navigating snow. The mobility assistance device **300** can be at least one flipper **301** for each mobility device **200**, and may alternatively or additively have one or more skis, skates, propellers, wings, sails, blades, balloons, floats, paddles, oars, flippers, cork-screws, winches, pressure tanks, rockets, a hover system, other suitable mobility assistance device, or combinations thereof.

FIGS. **68** and **69** illustrate that a flipper **301** can include a track **310**, a flipper pulley **320**, a track guide **330**, and a pulley cap **340**.

The track **310** of the flipper **301** can be identical to the track **210** of the mobility device **200**. The same materials and manufacturing processes can be used for the track **210** and the track **310** (e.g., which can improve manufacturability scalability and lower cost). The track **310** on the flipper **301** can be shorter than the track **210** of the mobility device **200**.

The flipper pulley **320** of the flipper **301** can be identical to the track drive pulley **220** of the mobility device **200**. For example, the flipper pulley **320** can have an outer wheel **324** and inner wheel hub **323**.

FIGS. **68** and **69** illustrate that the flipper **301** can include one flipper pulley **320**. The flipper **301** can include additional pulleys. The flipper pulley **320** can be adapted to rotate in tandem with the track drive pulley **220**. The flipper track **310** can move simultaneously with the track **210** of the mobility device **200**. The outside flipper track nubs **311** can be identical to the outside main track nubs **211**. The flipper pulley **320** and the track drive pulley can be linked via a rotatable axle sleeve **328**. One end of the rotatable axle sleeve **328** can be inserted in a mated interface (e.g., a hex interface as shown in FIGS. **68** and **69**) of the inner wheel hub **323** of the flipper pulley **320**. The ball bearing **319** and inner wheel hub plate **322** can be identical to the ball bearing **219** and the inner wheel hub plate **222**, respectively. The other end of the rotatable axle sleeve **328** can be inserted in a mated interface of the inner wheel hub **223** of the track drive pulley **220**. The rotatable axle sleeve **328** can rotate about the axle **149** for example with lubrication, a ball bearing, or other suitable bearing, or combinations thereof. The rotatable axle sleeve **328** can be molded from a rigid polymer or machined from aluminum, alternatively be nylon, polymer, metal, other suitable material, or combinations thereof.

FIGS. **68** and **69** illustrate that the flipper track guide **330** can keep the flipper track **310** centered on the flipper pulley **320** and realign the track **310** if the alignment is maladjusted. The track guide **330** can be made of lubricated nylon, other polymers, metal, carbon fiber, concrete, cardboard, wood, any other suitable material, or combinations thereof. The track **310** can slide over the track guide **330**. The track guide **330** can be lubricated, as shown. The track guide **330** can be injection molded, cast, extruded, machined, stamped, cut, any other suitable method of manufacture, or combinations thereof. The flipper track guide **330** can include additional support structures to improve the strength and shock absorb-

ing capabilities of the flipper track guide, for example a reinforced ribbing pattern machined or molded along the internal wall of the flipper track guide **330**, any suitable support structure, or combinations thereof. The flipper track guide **330** can be attached to at least one track guide arm **331**, for example two track guide arms **331**, and **332**.

The track guide arms **331**, **332** can be made of nylon, other polymers, metal, any other suitable material, or combinations thereof. The track guide arms **331**, **332**, can be reinforced with a ribbing pattern or any other suitable reinforcement structure along their length, which can improve strength and enable lighter weight, flexibility, torque and shock absorption of the track guide arms **331**, **332**. One of the track guide arms **331** can be attached to the rotatable axle sleeve **328**. The rotatable axle sleeve **328** can rotate inside of a ball bearing **329** located inside the track guide arm **331**. The ball bearing **329** can be held in place inside the track guide arm **331** by a snap ring **327** in a groove in the rotatable axle sleeve **328**.

FIG. **70** illustrates that the flipper assembly can have an outer composite cover **3331** and an inner composite frame **3332**. The outer composite cover **3331** and the inner composite frame **3332** can each be single, integral, unitary structures. For example, the outer composite cover **3331** can be made from the pulley cap **3400** integrated with the track guide arm **3320**, track guide **3301**, and the roller wheel cap **3370**. The inner composite frame **3332** can be made from the track guide arm **3310** integrated with the track guide **3302** and roller wheel cap **3360**. The inner composite frame **3331** can be integrated with the outer composite cover **3332**. The composite frame **3331** and/or composite cover **3332** can be made by molding, stamping, cutting, printing, or combinations thereof, from a single piece of material.

FIGS. **68** and **69** illustrate that the mobility assistance device **300** can include a pulley cap **340**. The pulley cap **340** can hold the second track guide arm **332** in place and rotate the guide arm **332** about the axle **149** when the axle **149** rotates the pulley cap **340**, thus actuating the entire flipper **301**. The pulley cap **340** can assist the track guide **330** and the flipper pulley **210** in keeping the track **310** aligned on the flipper pulley **320**.

FIGS. **30**, **32**, **33**, **68**, and **69** illustrate that the keyed inside **346** of the axle cap **341** can be mated to the keying **163** of the axle **149**, such that the axle cap **341** can rotate with the axle **149**, and the pulley cap **340** can be keyed to interface and rotate with the axle cap **341**. A hex, square, or triangular keying shape can be used for the keying of the inside **346** of the axle cap **341**. The outside of the hex cap **341** can be keyed to fit into a keyed interface in a pulley cap **340**. The pulley cap **340** can include a gap **344** having dimensions to hold the second track guide arm **332** in place, for example the pulley cap **340** can include a keying on the inside edge **343** of the pulley cap **349** mated to a keying **347** on the second track guide arm **332** such that when the pulley cap **340** rotates, the track guide arm **332** also rotates, which actuates the flipper **301** when the mobility assistance module **140** rotates the axle **149**. The gap **344** can be from about 10 mm (0.4 in.) to about 60 mm (2.4 in.), for example about 38 mm (1.5 in.). The pulley cap **340** can be fastened to the axle **149** using a nut **348** over the threaded end of the axle **149**. The outward facing portion of the pulley cap **340**, can be convex, or alternatively a set of convex ridges arranged radially outward from the center of the pulley cap, such that if the robot system **10**, were somehow positioned on a side, the convexity will cause the robotic system **10** to roll to either side and allow the tracks **310** to contact a surface and regain mobility. The pulley cap **340** can be made of nylon, but may alternatively be made of other polymers, metal, carbon fiber, concrete, cardboard, wood, or

any other suitable material. The pulley cap **340** can be manufactured using a machining process, injection molded, cast, extruded, stamped, any other suitable method of manufacture, or combinations thereof.

The inside edge **343** of the pulley cap **340** can be mated with the rounded edge of the inside nubs **316** of the track **310**, for example, to guide the alignment of the track **210**, and prevent the inside nubs **316** from carrying foreign objects in between the track **310** and the flipper pulley **320**. The pulley cap **340** can have ribs, vanes, fins, or combinations thereof; that can mate with the nubs on the track.

The actuation granularity of the flipper may be tuned by changing the gearbox **142** in the drive assistance module **140**. The mobility assistance module **140** can be adapted to rotate the flipper **301** more than 360° , about 360° (i.e., a revolution), or less than 360° (e.g., less than an entire revolution), for example about 345° . The rotation of the flipper **301** can be limited by the control software, and/or electronically, and/or mechanically limited, for example by a shear pin.

The mobility assistance module **140** can be omitted from the device. The position of some or all of the flippers can be manually actuated by removing a pin **168** in manually actuated mount **167**, manually actuating the axles **169**, and replacing the pin **168**. The flipper positions may be selected using a multiple, discrete position interface with a ball detent or friction clamp design, any other suitable fastening device or method, or combinations thereof.

The flipper track **310** can be guided by a roller wheel **335**. The roller wheel **335** can be capped on each side by roller wheel caps **336**, **337** any or each of which can be attached to the track guide arms **332** and **331** respectively, and adapted to enable the roller wheel **335** to rotate freely. As shown in FIGS. **17** and **18**, the inner edge **339** of the track guide cap can be mated to the inside nubs **316** of the flipper track **310**. The track guide caps or roller wheel caps **336** and **337** can be made of nylon, another polymer, a metal, or combinations thereof.

FIG. **71** illustrates that the flippers **301** can be retracted, contracted, or rotationally folded, as shown by arrows **50**, into a compact shape, for example for storage or carrying. The robotic system **10** can have a compact length **368** of about 43 cm (17 in.).

The flippers **301** at one or both ends of the system **10** can have a safety release coupling that can release the flippers **301** so the flippers **301** can be rotated, as shown by arrow **50**, with respect to the body **20**. The safety release couplings can have mechanical, electro-mechanical, magnetic couplings, or combinations thereof. The safety release couplings can have detents and/or ball bearings. The safety releasing coupling can release the flippers **301** when the torque, as shown by arrow **400** in FIG. **28**, applied to the flippers **301** exceeds from about 15 Nm (11 lb-ft.) to about 145 Nm (107 lb-ft.), more narrowly from about 30 Nm (22 lb-ft) to about 125 Nm (92.2 lb-ft.), for example about 100 Nm (74 lb-ft.) of torque at the axis of rotation. For example, the system **10** can be dropped or slammed against the ground or a wall to release the flippers **301** so the flippers **301** can rotate freely with respect to the body **20**.

As shown in FIG. **72**, both flippers **301** can be extended, as shown by arrows **50**, to achieve the maximum length of the device. The extended length **370** of the robotic system **10** with both flippers **301** extended can be equal to or more than about 69 cm (27 in.). For example, the robotic system **10** can be equal to or greater than about 40%, 50%, 60%, 80%, 100%, 150% or 175% longer from the contracted configuration to the expanded configurations of the robotic system **10**.

FIGS. **6e** and **6f** illustrate that if the length of the mobility assistance devices **300** is long enough, the robotic system **10**

can be equal to or greater than about 200% longer from the contracted configuration to the expanded configurations of the robotic system **10**. The extended length of both flippers **301** can enable the robotic system **10** to climb stairs.

FIG. **73** illustrates that at least one or a pair of the (e.g., front) flippers **301** may be rotated, as shown by arrows **50**, to a higher angle to enable the robotic system **10**, for example to climb an obstacle while the other (e.g., rear) flippers may be folded or extended.

FIG. **74** illustrates that the robotic system **10**, may be elevated off of a surface **372** when both flippers **301** are rotated to point down. This functionality may be useful for navigating terrains with pressure sensitive or hostile conditions, such as chemical spills, minefields, or any other hazardous terrain, or to raise the chassis of the system **10** above the surface, such as when passing through water obstacles (e.g., ponds, puddles, moats, streams, rivers).

As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the variations of the invention without departing from the scope of this invention defined in the following claims. More than one range or example of quantities can be provided for a characteristic as alternative contemplated ranges and examples. Elements, characteristics and configurations of the various variations of the disclosure can be combined with one another and/or used in plural when described in singular or used in plural when described singularly.

We claim:

1. A robotic system comprising:

a chassis;

a first track drive system attached to the chassis, wherein the first track drive system comprises a track and a drive pulley;

a heat sink comprising a vane on the outside of the chassis, wherein the heat sink is attached to the outside of the chassis;

a motor located in the chassis, and wherein a first end of a heat pipe is attached to a motor and wherein a second end of the heat pipe is attached to the heat sink; and

a fluid circulation device;

wherein the chassis comprises a channel having an intake port and an exhaust port, and wherein the fluid circulation device is in the channel.

2. The system of claim 1, wherein the circulation device is configured to blow an ambient fluid across the vane.

3. The system of claim 1, wherein the fluid circulation device is outside of the chassis.

4. The system of claim 1, wherein the fluid circulation device comprises a fan.

5. The system of claim 1, wherein the heat sink is in the channel.

6. The system of claim 1, wherein the chassis is sealed fluid-tight.

7. The system of claim 1, further comprising a first payload removably attached to the chassis, and wherein the first payload comprises a rotatable camera.

8. The system of claim 1, further comprising a battery located through an opening in a side panel of the chassis, and further comprising a closable door located on the opening.

9. The system of claim 1, further comprising, a remote control unit, wherein the remote control unit is waterproof.

10. The system of claim 1, further comprising an audio transducer and wherein the audio transducer is waterproof.

11. A robotic system comprising:
a chassis;
a first track drive system attached to the chassis, wherein
the first track drive system comprises a track and a drive
pulley; 5
a heat sink comprising a vane on the outside of the chassis;
and
a heat pipe having a first end and a second end;
a motor located in the chassis, and wherein a first end of the
heat pipe is attached to a motor and wherein a second end 10
of the heat pipe is attached to the heat sink.
12. The system of claim 11, wherein the heat pipe comprises a fluid.
13. The system of claim 11, further comprising a fluid
circulation device. 15
14. The system of claim 11, wherein the chassis is sealed
fluid-tight.
15. The system of claim 11, further comprising a circulation
device configured to blow an ambient fluid across the
vane. 20
16. The system of claim 15, wherein the fluid circulation
device is outside of the chassis.
17. The system of claim 15, wherein the fluid circulation
device comprises a fan.
18. The system of claim 11, further comprising, a battery 25
located through an opening, in a side panel of the chassis, and
further comprising a closable door located on the opening.
19. The system of claim 11, further comprising a remote
control unit, wherein the remote control unit is waterproof.
20. The system of claim 11, further comprising an audio 30
transducer and wherein the audio transducer is waterproof.

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